Exhibit B

UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, DC

Honorable MaryJoan McNamara, Administrative Law Judge

In the Matter of CERTAIN LASER ABRADED DENIM GARMENTS	Investigation No. 337-TA-930

MEMORANDUM AND POINTS OF AUTHORITIES IN SUPPORT OF H & M HENNES & MAURITZ L.P. AND H & M HENNES & MAURITZ AB'S MOTION FOR SUMMARY DETERMINATION OF INVALIDITY OF THE ASSERTED PATENTS ON THE BASIS OF INDEFINITENESS

Table of Contents

Table of Contents (continued)

TABLE OF AUTHORITIES

RULES

Pursuant to Rule 210.18 and Ground Rule 3, Respondents H & M Hennes & Mauritz L.P. and H & M Hennes & Mauritz AB (collectively, "H&M"), by and through undersigned counsel, move for summary determination of invalidity of each of the following of the asserted claims of the remaining Asserted Patents on the basis of indefiniteness pursuant to 35 U.S.C. §112[1]:

ASSERTED PATENTS	INVALID ASSERTED CLAIMS DUE TO INDEFINITENESS
6,140,602	1, 14, 15, 73, 83, 85, 99, 112, 120, 122-124, 141-143
6,819,972	1, 2, 4-6, 11, 12, 17-19, 63, 64, 72, 77, 78, 92-95
6,664,505	1, 49-51

Each of these claims (the "Indefinite Claims") contains at least one term that fails to meet the legal standard for definiteness.[2] The '602 Patent and '972 Patent each include claim terms that are left solely to the subjective aesthetic determination of a user: what is "undesirable" and what is "imperfect"? The '972 Patent further includes claim terms that the inventors themselves coined for the purposes of the patent, but then failed in any way to clearly define: "effective applied energy," "effective applied power," and "effective applied power levels." And the asserted claims of the '505 Patent each include the hopelessly vague claim term "mathematical operation" – with no limits as to what the claimed "mathematical operation" might include.

A patent's specification must "conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as [his] invention." 35 U.S.C. § 112 ¶ 2.[3] The Supreme Court recently reiterated that a patent claim is invalid for failing

---

1 This Motion addresses all the remaining asserted claims except claims 56-59 of the '972 Patent. H&M asserts that claims 56-59 of the '972 Patent are invalid, but for reasons that are not addressed in this motion.

2 Respondents submitted briefing on the same claims and the same theories of invalidity as part of claim construction. *Respondents' Opening Claim Construction Brief*, §§ V(B)(2), V(B)(5), V(D), V(E)(1), and V(E)(3) (EDIS Doc. ID No. 549145 (Jan. 9, 2015)); *Respondents' Rebuttal Claim Construction Brief*, §§ III(A)(2), III(A) (5), III(B), III(C)(2), and III(C)(3) (EDIS Doc. ID No. 560482 (July 10, 2015)). At the time of the submission of this motion, a claim construction ruling has not yet been issued.

3 Paragraph 2 of 35 U.S.C. § 112 was replaced with newly designated § 112(b) when §4(c) of the America Invents Act, Pub.L. No. 112-19, took effect on Sept. 16, 2012. Because the applications resulting in the

to meet this requirement of "definiteness" if it "fail[s] to inform, with reasonable certainty, those skilled in the art about the scope of the invention." *Nautilus, Inc. v. Biosig Instruments*, 134 S. Ct. 2120, 2124 (2014). As set forth in further detail below and in the exhibits submitted herewith, the claim terms included in each of the Indefinite Claims fail to meet this standard, and H&M respectfully requests that a summary determination be entered finding them invalid as indefinite pursuant to 35 U.S.C. § 112 ¶ 2.

I. LEGAL STANDARD: SUMMARY DETERMINATION

Summary determination is appropriate where the "pleadings and any depositions, answers to interrogatories, and admissions on file, together with the affidavits, if any, show that there is no genuine issue as to any material fact and that the moving party is entitled to a summary determination as a matter of law." Rule 210.18(b). Summary determination under Rule 210.18(b) is analogous to summary judgment under Fed. R. Civ. P. 56(c). *Certain Asian-Style Kamaboko Fish Cakes*, Inv. No. 337-TA-378, Commission Notice, 1996 WL 1056341 at 16 (Sept. 25, 1997) (Westlaw pagination). Therefore, federal case law interpreting Rule 56(c) is useful in determining whether summary determination is appropriate.

When seeking summary determination, the moving party carries the initial burden of demonstrating the absence of any genuine issue of material fact. *Celotex Corp. v. Catrett*, 477 U.S. 317, 323 (1986). To determine whether the party has met this burden, "the [ALJ] must accept all evidence presented by the non-movant as true, must view all of the evidence in the light most favorable to the non-movant and must draw all justifiable inferences in favor of the non-movant." *Certain Lens-Fitted Film Packages*, Inv. No. 337-TA-406, Order No. 7 at 3 (July 10, 1998) (citations omitted). The moving party is entitled to summary determination "[w]hen

---

patents at-issue in this Investigation were filed before that date, this Motion refers to the pre-AIA version of §112. The relevant statutory language is the same.

the record taken as a whole could not lead a rational trier of fact to find for the non-moving party." *In the Matter of Certain Optical Disk Controller Chips & Chipsets*, Inv. No. 337-TA-523, Order No. 75 (June 27, 2005) (citations omitted).

Here, H&M seeks summary determination on issues that are questions of law: that the Indefinite Claims are invalid for failing to meet the definiteness requirements pursuant to 35 U.S.C. § 112 ¶ 2. "A determination of claim indefiniteness is a legal conclusion that is drawn from the court's performance of its duty as the construer of patent claims." *Personalized Media Communications, L.L.C. v. Int'l Trade Comm'n*, 161 F. d 696, 705 (Fed. Cir. 1998) (applying pre-*Nautilus* standard for indefiniteness); *see also, The Dow Chemical Co. v. NOVA Chemicals Corp. et al.*, 2015 U.S. App. LEXIS 15191 at *7-8 (Aug. 28, 2015) (noting that indefiniteness is a question of law).

II. LEGAL STANDARD: INDEFINITENESS

Under 35 U.S.C. § 112, a patent's specification must "conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as [his] invention." 35 U.S.C. § 112. ¶ 2. Affirming the importance of providing "clear notice of what is claimed," the Supreme Court recently articulated the applicable legal standard under Section 112 ¶ 2: "[A] patent is invalid for indefiniteness if its claims, read in light of the specification delineating the patent, and the prosecution history, fail to inform, *with reasonable certainty*, those skilled in the art about the scope of the invention." *Nautilus*, 134 S. Ct. at 2124 (emphasis added). Indefiniteness under section 112 is a "delicate balance": "[o]n the one hand, the definiteness requirement must take into account the inherent limitations of language. Some modicum of uncertainty, the Court has recognized, is the 'price of ensuring the appropriate incentives for innovation.'" *Id.* at 2128. At the same time, a patent must be precise enough to afford clear notice of what is claimed, thereby "appris[ing] the public of what is still open to

them." *Id*. Otherwise, there would be a "zone of uncertainty which enterprise and experimentation may enter only at the risk of infringement claims." *Id.* at 2129.

The Federal Circuit has applied *Nautilus* in finding patent claims invalid for being unduly subjective, holding the "[t]he claims, when read in light of the specification and the prosecution history, must provide objective boundaries for those of skill in the art." *Interval Licensing LLC v. AOL, Inc.*, 766 F. 3d 1364, 1371 (Fed. Cir. 2014). "[T]here is an indefiniteness problem if the claim language might mean several different things and no informed and confident choice is available among the contending definitions." *Id.* (quoting *Nautilus*, 134 S. Ct. at 2130 & n. 8) (internal quotation marks omitted).

In *Interval Licensing*, the Federal Circuit found the term "unobtrusive manner" to be indefinite, noting that this was a term of degree, "purely subjective," and that "[t]he hazy relationship between the claims and the written description fail[ed] to provide the clarity that the subjective claim language need[ed]."*Id.* at 1370-74. The district court observed that the term "unobtrusive manner" was "highly subjective and, on its face, provides little guidance to one skilled in the art . . . and the claim language offers no objective indication of the manner in which content images are to be displayed to the user." *Id*. at 1371. The Federal Circuit agreed with the district court, observing that "whether something distracts a user from his primary interaction depends on the preferences of the particular user and the circumstances under which any single user interacts with the display." *Id*. As discussed below, many of the Indefinite Claims are purely subjective, and thus fail to provide the requisite certainty to someone with skill in the art as to what is claimed in the Asserted Patents.

The Federal Circuit has also found claims terms that "are completely dependent on a person's subjective opinion" to be indefinite, even under the narrower "insolubly ambiguous"

standard for indefiniteness that was applied prior to the Supreme Court's decision in *Nautilus*. *Datamize, LLC v. Plumtree Software, Inc.*, 417 F.3d 1342 (Fed. Cir. 2005) *abrogated on other grounds* by *Nautilus*, 134 S. Ct. at 2130. In *Datamize*, the Federal Circuit found the claim term "aesthetically pleasing" to be indefinite because it lacked "a workable objective standard." *Id.* at 1350. More specifically, the Federal Circuit instructed – again, under the even more restrictive "insolubly ambiguous" standard for finding claim terms indefinite – that:

> The scope of claim language cannot depend solely on the unrestrained, subjective opinion of a particular individual purportedly practicing the invention. Some objective standard must be provided in order to allow the public to determine the scope of the claimed invention. Even if the relevant perspective is that of the system creator, the identity of who makes aesthetic choices fails to provide any direction regarding the relevant question of how to determine whether that person succeeded in creating an "aesthetically pleasing" look and feel for [the device at-issue]. A purely subjective construction of "aesthetically pleasing" would not notify the public of the patentee's right to exclude since the meaning of the claim language would depend on the unpredictable vagaries of any one person's opinion of the aesthetics. While beauty is in the eye of the beholder, a claim term, to be definite, requires an objective anchor. Thus, even if we adopted a completely subjective construction of "aesthetically pleasing," this would still render [the patent at-issue] invalid.

Id. at 1350-51 (internal citations omitted).

Recent district court decisions are to the same effect. For example, in *Prolifiq Software Inc. v. Veeva Sys., Inc.*, the Northern District of California recently found patent claims using the term "differently versioned" to be indefinite. *Prolifiq Software Inc. v. Veeva Sys., Inc.*, C.D.C.A. Case No. 13-cv-03644 SI, 2014 U.S. Dist. LEXIS 108630 at *16-20 (N.D. Cal. Aug. 6, 2014). That the patent specification provided "clear examples" of differently versioned content elements was not sufficient to provide "an objective standard for determining what is meant by the term 'differently versioned.'" *Id*. at *19.

> [T]o determine the scope of a claim, a person skilled in the art must know not only what falls inside the scope of the claim term, but also what falls outside of it. This knowledge provides a person skilled in the art with the boundaries of the invention . . . . Stating examples of differently versioned digital content elements

> only provides information about when something is a differently versioned digital content element, but it does not provide information about when something is not a differently versioned digital content element. Thus, the examples do not necessarily provide information about what falls outside the scope of the claims.

Id. at * 20-21. The district court found that claim language relying solely on the unrestrained, subjective opinion of an individual practicing the invention would fail to provide a person skilled in the art with the "reasonable certainty" required under the Supreme Court's test for indefiniteness as articulated in *Nautilus*. *Id.* at *17. As set forth in further detail below, the Indefinite Claims fail to meet the standard for definiteness for the same reasons.

III. BACKGROUND OF THE TECHNOLOGY

A. Summary of The Asserted Patents.

Three patents remain at-issue in this Investigation: U.S. Patent No. 6,140,602 ("the '602 Patent"), U.S. Patent No. 6,819,972 ("the '972 Patent"), and U.S. Patent No. 6,664,505 ("the '505 Patent") (the "Asserted Patents"). The Asserted Patents contain 367 total claims, of which Complainants currently assert the following against H&M (the "Asserted Claims"):

ASSERTED PATENTS	ASSERTED CLAIMS OF THE ASSERTED PATENTS
6,140,602	1, 14, 15, 73, 83, 85, 99, 112, 120, 122-124, 141-143
6,819,972	1, 2, 4-6, 11, 12, 17-19, 56-59, 63, 64, 72, 77, 78, 92-95
6,664,505	1, 49-51

Complainants Revolaze, LLC's and Technolines, LLC's Fourth Supplemental Objections and Responses to Respondents' First Set of Joint Interrogatories, Supplementing Interrogatory No. 1 (Exhibits O-R). The purported inventions disclosed in each of the Asserted Patents – the earliest of which was filed on April 29, 1997 – generally relate to methods of controlling a laser to form certain effects on materials, such as denim.

For example, the following figure is taken from the ‘602 Patent:

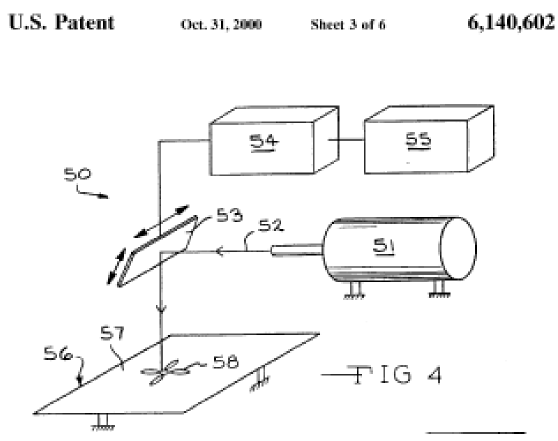


Exhibit 1, ‘602 Patent, Figure 4. As described by the inventors, “FIGS. 1 through 9 are schematic views of a laser method of forming designs on thin fabrics and leathers in accordance with this invention…FIG. 4 illustrates a method in which a mirror is moved to direct the laser beam onto the surface of the fabric.” ‘602 Patent, Col. 2:25-29, 2:39-41. As further described in the specification and claims of the ‘602 Patent, the claimed method(s) recite the control of certain operating parameters to control the laser, such as speed. *See e.g.*, ‘602 Patent, Col. 1:54-59 (“The method uses a laser beam to slightly penetrate the surface of the product at a controlled specific speed. The laser beam is directed at the product either directly or through mirrors, shutters or lenses. The speed of the laser with beam relative to the surface of the product is controlled within a predetermined range”). The parameters are controlled to transfer a design to fabrics while “overcoming the technical barriers of carbonization, complete melting and/or burn-through.” ‘602 Patent, Col. 2:1-2.

In most of the asserted claims of the ‘602 Patent, the method involves determining and using a laser speed that is greater than a minimum (sometimes referred to as “threshold”) speed but below a maximum speed. *See e.g.*, ‘602 Patent, Claims 1, 14, 15, 73, 83, 85, 99, 112, 120-124, 141-143. The threshold speed is a laser speed below which the laser will move too slowly

relative to the material and cause what the claims call "undesired" effects on the material. *See e.g.*, '602 Patent, Col. 3:45-49, Claim 1. The maximum speed is a laser speed above which the laser will move to quickly relative to the material and will not form what some of the claims recite as a "desired" change to the material. *See e.g.*, '602 Patent, Col. 3:47-51, Claim 1.

The '505 Patent contains similar figures and descriptions:

U.S. Patent Dec. 16, 2003 Sheet 1 of 22 US 6,664,505 B2

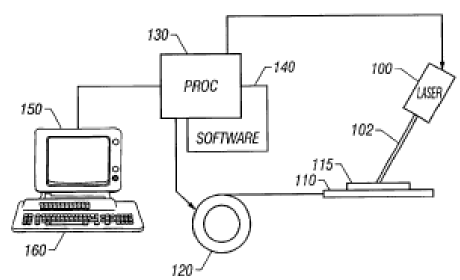


FIG. 1

Exhibit 2, '505 Patent, Figure 1, Col. 1:45-50 ("FIG. 1 shows a block diagram of the basic system of the present invention including the processor, and the marking device being a laser"). According to the inventors, the '505 Patent "teaches additional tools and techniques intended for controlling a laser to produce an output beam that changes the look of a specified garment or material in a new way," this time using a "mathematically-based process." '505 Patent, Col. 1:30-36. Much like the '602 Patent, the '505 Patent specification describes controlling the laser, where the "user can interact with the effect selection by entering parameter values, modifying looks and producing a final pattern to be written on to the material." '505 Patent, Col. 2:60-63.

The method recited in each of the asserted claims of the '505 Patent involve performing what the claims call a "mathematical operation" based on input parameters to form "values which are individualized for each of a plurality of areas." '505 Patent, Claims 1, 49-51. The method then involves using the formed values to control a laser to "change a look" of a textile

material. *Id.*

The '972 Patent contains similar figures and descriptions:

U.S. Patent Nov. 16, 2004 Sheet 1 of 13 US 6,819,972 B1

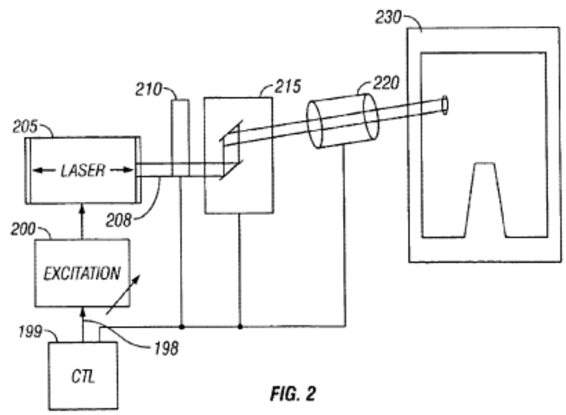


FIG. 2

Exhibit 3, '972 Patent, Figure 2, Col. 3:17 ("FIG. 2 shows a controllable lasing system"). Similar to the '602 Patent and the '505 Patent, the purported inventions in the '972 Patent are described by the inventors as "new laser scribing devices and techniques to simulate specified worn looks on fabrics and garments." '972 Patent, Col. 2:42-45. "These worn looks can include abrasion effects which simulate the look of a worn garment, whisker effects, frayed effects." '972 Patent, Col. 3:30-32. This time, the inventors purport to "introduce" a concept they coin as "effective applied power" and/or "effective applied energy," which is controlled such that it changes the look of textile materials. '972 Patent, Col. 3:40-65. According to the inventors, effective applied energy "includes the amount of energy that is effectively applied to an area of a material. That area can be any size or shape. The 'effective applied energy' can include EDPUT, but also includes changing scan line speed, power level or speed level or duty cycle level of the laser. It includes changing the distance of the laser to the material, which can defocus the laser, and thereby change the EDPUT. It also includes effective applied power being applied in multiple sessions or times, by applying multiple passes, *e.g.*, of fixed power etc. The

effect is to apply more energy to some areas than to others." *Id*.

The asserted claims of the '972 Patent generally involve controlling the laser by using stored information concerning an "effective applied power" or an "effective applied energy." *See e.g.*, '972 Patent, Claims 1, 2, 4-6, 11, 12, 17-19, 63, 64, 72, 77, 78, 93-95. In some instances, the laser is controlled to form a pattern on the material (*see e.g.*, claims 1, 56, and 78), while in other instances the laser changes the color of the material (*see e.g.*, claims 72 and 92). In some instances, the claims methods involve storing information about "effective applied power levels" to be applied by a laser during its scan lines. *See* '972 Patent, Claim 1. In some instances, the methods also involve controlling the scan lines by controlling an "energy density per unit time" that "depends on [the] effective applied power levels." *See e.g.*, *id.* And in some instances, the scan lines will have "levels of effective applied power which change within a single scan line." *Id.* In some instances, the claimed methods involve defining a pattern by "selecting a plurality of areas on a display" and then "associate[ing] a level of abrasion with each of the plurality of areas." *See e.g.*, '972 Patent, Claim 56.

B. Prior Use of Laser Technology.[4]

The Asserted Patents are not the first examples of the use of lasers to mark, etch, or otherwise create effects on things. The prior art – some dating to the 1980s – is filled with examples of using lasers to do exactly that. *See e.g.*, U.S. Patent No. 4,847,184 to Taniguchi, et al., (June 11, 1989) (method of using a laser to transfer an image onto a substrate that is carbonizable or discolorable); U.S. Patent No. 4,861,620 to Azuma et al. (August 29, 1989) (method laser marking using a pigment coating and a focused laser beam to affect the internal

[4] The prior art to the Asserted Patents is not limited to that which is identified here in this Motion. The summary set forth in this section is included solely for purposes of context in connection with the indefiniteness analysis set forth herein. H&M's assertions of invalidity as to all of the remaining Asserted Claims for all of the remaining Asserted Patents on the basis of invalidity in light of prior art are the subject of anticipated expert testimony and separate motions for summary determination.

molecular structure of the coating to change pigment color); U.S. Patent No. 4,901,089 to Bricot (February 13, 1990) (method and device for recording pictures by laser involving ablation of top layer out of several placed on a substrate); U.S. Patent No. 5,017,423 to Bossman et al. (May 21, 1991) (method of engraving a pattern onto a substrate to form a pattern) (collectively attached hereto as Exhibit 4).

The Asserted Patents are also not the first examples of the use of lasers to mark fabrics and textiles, such as denim. For example, the following figure is taken from U.S. Patent No. 5,567,207 to Lockman, et al. (October 22, 1996), titled “Method for Marking and Fading Textiles with Lasers”:

U.S. Patent Oct. 22, 1996 Sheet 1 of 2 5,567,207

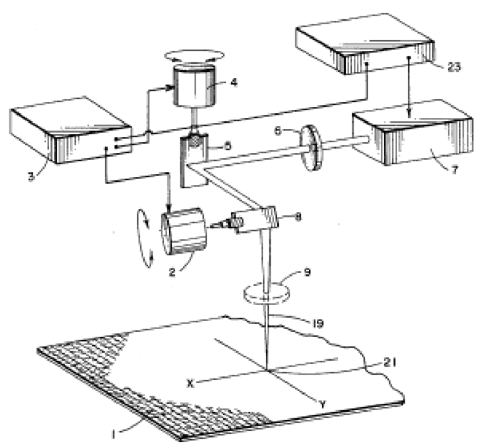


FIG. 1

Exhibit 5, ‘207 Patent, Figure 1. The applicants for the ‘207 Patent – issued six months prior to the filing of the first of the Asserted Patents – described their invention as relating to “using lasers to simulate conventional laundering techniques, such as stone washing, echo ball washing and acid washing without the use of water or chemicals.” ‘207 Patent, Col. 1:7-11. More particularly, the applicants for the ‘207 Patent described their invention as “a method where intense laser radiation is directed onto a pre-dyed textile material such as denim.” ‘207 Patent,

Col. 1:21-23.

As is clear from at least this disclosure, the identification and control of laser operating parameters was also well known before the filing dates of any of the Asserted Patents. The applicants for the ‘207 Patent discussed the control and adjustment of various laser parameters, including laser speed, as follows:

> The laser parameters such as wavelength, average power, pulse duration, power density, and scan speed are adjusted to provide efficient absorption into the dye components of the textile material…The laser beam scan rate, power density, average power, pulse width, and repetition rate are synchronized to the speed of the textile material such that the desired fading patter is created.

‘207 Patent, Col. 1:23-43.

Even before the ‘207 Patent, the control of laser operating parameters, such as power and relative speed, was known when using lasers with fabrics. *See*, Exhibit 6, Soviet Union Patent SU 1,559,794 to Grigoryan et al., titled “Method of Making Patterns on Long Material” (December 22, 1989) (original and translation included). The disclosure in this patent from the late ’80s describes the inventions as “pertain[ing] to manufacturing processes for textile, garment, and leather production.” *Id.*, p. 1 (translation). The disclosure goes on to state:

> The exposure conditions, including the laser output power, the radiation wavelength, and the relative travel speeds of the laser beam and the work material, were chosen so as to obtain the required results. For example, no visible pattern is obtained if the laser output power is less than 10W or if the relative travel speed is greater than 1 m/s. Conversely, the material is completely destroyed if the laser output power is greater than 100W or if the relative travel speed is less than 0.1 m/s.

Id., p. 2 (translation).

IV. ALL CLAIMS IN THE '602 AND '972 PATENTS THAT RECITE AN ELEMENT RELYING ON THE SUBJECTIVE AESTHETIC DETERMINATION OF THE USER AS TO WHAT IS "UNDESIRED" OR "UNDESIRABLE" ARE INDEFINITE.

A. The "Undesired" And "Damage" Claim Terms In The '602 Patent Are Subjective, And Are Indefinite Under Section 112, ¶ 2.

Claim 1 of the '602 Patent is directed to "a method of using a laser for forming a design on a product," comprising "determining … a threshold speed below which at least one of ***carbonization, undesired burn through or undesired melting*** of the material of the product will occur…" '602 Patent, Claim 1. The terms "undesired" and "undesirable" are used in similar fashion in claim 73 ("…determining, for said specific material, a threshold speed of scanning for said laser, below which ***undesired damage*** to the material will be caused…"), claim 99 ("…that will cause a desired structural change of the material ***without undesired damage*** to the material…"), claim 112 ("…determined minimum operating speed for the material being used at which ***undesired damage*** to the material will be formed…"), claim 120 ("…to form a pattern in the material which changes the material ***without undesirably damaging*** the material…"), and claim 141 ("…causes a pattern which can be seen to be formed in the material ***without undesirably damaging*** the material…").

As explained by Respondents' expert, Dr. Cole (and not disputed by Complainants' expert), the terms "undesired" and "undesirable" do not have generally accepted meanings to one of ordinary skill in the art. Exhibit 7, *Opening Expert Report of Christine W. (Jarvis) Cole, Ph. D. on Claim Construction Issues*, December 19, 2014 ("Cole Report"), ¶ 51; Exhibit 8, *Rebuttal Expert Report of Frank Pfefferkorn, Ph. D Regarding Claim Construction Issues*, January 16, 2015 ("Pfefferkorn Report") ¶¶ 52-59. Rather, according to Dr. Cole, what is "undesirable" is an inherently subjective concept, "the meaning of which is determined by individual opinion." Cole Report, ¶¶ 51-52. And the direction in the '602 Patent as to which effects are to be avoided

pursuant to the claim language is inconsistent, providing no further clarity as to what is included – or what is not included – in the scope of the "undesired" claims. *Id.*, ¶¶ 53-58. Neither the '602 Patent nor the prosecution history provide any objective standard for determining the "undesired" or "undesirable" effects that the claims instruct a user to avoid. Rather, the intrinsic evidence provides contradictory direction as to what might (or might not) be included within the scope of "undesirability" as recited by the claims of the '602 Patent.

One federal district court reviewing similarly subjective terms in the wake of *Nautilus* noted that claim language relying solely on the unrestrained, subjective opinion of an individual practicing the invention fails to provide a person skilled in the art with the "reasonable certainty" required under the Supreme Court's test for indefiniteness. *Prolifiq*, 2014 U.S. Dist. LEXIS 108630 at *15-28; *see also Datamize LLC*, 417 F. 3d at 1350 (finding the claim term "aesthetically pleasing" indefinite insofar as "it is completely dependent on a person's subjective opinion"). As set forth in further detail below, independent claims 1, 73, 99, 112, 120, and 141of the '602 Patent are invalid for the same reason. And because the remaining asserted claims from the '602 Patent all depend on the above-referenced independent claims (claims 14, 15, 83, 85, 122-124, 14-143) and add no further objective clarification to what is "undesired," the remaining asserted dependent claims are also invalid as indefinite under 35 U.S.C. § 112 ¶ 2.

1. A Person Skilled in the Art Would Consider the Scope Of What Kind Of Damaging Effects Are "Undesirable" As Claimed In The '602 Patent To <u>Be Determined By Subjective Opinion.</u>

As described by Respondents' expert, Dr. Cole, the terms "undesired" and "undesirable" are subjective terms that do not have a generally accepted meaning to one with ordinary skill in the art. Cole Report, ¶¶ 51-52. Similarly, Dr. Cole explains (and Dr. Pfefferkorn does not dispute) that the terms "damage" and "damaging" do not have a single meaning to one with ordinary skill in the art. Cole Report, ¶ 55; Pfefferkorn Report, ¶¶ 52-59. Rather, there are a

number of different types of known "damage." Cole Report, ¶ 55. For example, in the application of a laser to a material such as denim, photodecomposition of the indigo dye may result in either a color change, or complete or partial evaporation of the indigo dye. *Id.* The application of a laser to a material may also result in abrasion that reduces the diameter of the yarns in the material. *Id.* However, these types of damage are not described in the '602 Patent, and it is unclear whether any of these types of damage that would be known to one of ordinary skill in the art would meet the claim limitations reciting "damage." *Id.*

Further, the '602 Patent, its specification, and the prosecution history provide no further clarity to one of ordinary skill in the art at the time of the filing of the patent to give any certainty about the scope of the claimed damage – whether "undesired" or not – to the material that the claims purport to avoid. *Id.*, ¶¶ 53-58. Rather, the '602 Patent seems only to confirm that some types of "damage" could be both desirable *and* undesirable, thereby confirming the inherently subjective nature of what kinds of effects fall within the scope of being "undesirable." *Id.*, ¶¶ 56-57.

2. There Is ***No*** Guidance In The Intrinsic Evidence As To What Falls Within – Or Does Not Fall Within – The Scope Of The "Undesired" Or "Damage" Claim Terms.

There is no specific definition of the terms "undesired," "undesirable" or "damage" set forth in the '602 Patent. In fact, the term "damage" appears nowhere in the specification of the '602 Patent. And term "undesirable" appears only once, but is not used to modify the "burn through," "damage," or other effects referenced by the claims. Instead, it appears in the Background of the Specification describing prior art uses of lasers in the fabric industry:

> When such use was attempted, the laser beam caused carbonization, complete melting, and/or burn through at the point of contact. This resulted in complete penetration and the formation of **an undesirable hole or defect** in the fabric or leather.

'602 Patent, Col. 1:35-40. The specification and prosecution history of the '602 Patent in some places go to great effort to distinguish the purported invention from such prior uses of lasers and various apparently "undesired" or "damaging" effects such as holes or defects.

For example, the specification states that the claimed invention (*i.e.*, the "specific identification and control of speed") provides "the keys to preventing carbonization, complete melting and/or burn-through of the fabric." *Id.*, Col. 3:37-40. The specification goes further to state that "[i]t has been discovered that there is a Critical Operating Speed above which the propensity to not form a design on the fabric increases, and below which the propensity to cause burn-through, complete melting and/or carbonization increases." *Id.*, Col. 4:29-33.

The prosecution history also emphasizes this distinction over prior uses of lasers. In distinguishing over prior art cited by the Examiner, the Applicants amended their claims to add the "without undesireably [sic] damaging" claim terms in their April 27, 1997 Response.

> The inventor of the present invention recognized special operational parameters which allow a focused beam of radiation, such as a laser beam, to be used to form a design or pattern in the material without undesireably damaging the material. This is done by determining parameters of control for a specific material with specific characteristics. The preferred embodiment calls these parameters a critical operating speed. This is the speed that the laser beam must travel relative to the material being changed in order to form a pattern/design, but still avoid damage to the material.

Complaint, App. C, '602 File History, Response to Office Action dated 4/27/1997, p. 51 (EDIS Doc. ID No. 540354 (Aug. 18, 2014) (attached to public version of original complaint)). The applicants further explained that their invention identified the special parameters that allow a design to be formed on a product without damage to the product:

> As described above, an important realization of the present invention is the special parameters which allow a design to be formed on a product without damage to the product. There is nothing in the prior art references which teach or suggest how to form a pattern on the material without undesirably damaging the material.

Id., p. 52. Thus, the Applicants argued that the '602 Patent differs from other uses of lasers in that it identifies the relative speed between the material and the laser as being the critical parameter to control to form a graphic on the material while preventing damage to the material:

> Claim 1 has been amended herewith to recite elements of this method. An initial step requires determining, for a material being used, a maximum speed of said material relative to the laser for a given laser power that will result in a perceivable change being formed, and a threshold speed below which at least one of carbonization, undesired burn through or melting of the fabric will be caused. This has been found by the inventors to be crucial for forming the proper indicia on the material without burning.

Id., p. 53.

In some cases, the claims read somewhat consistently with these descriptions of avoiding complete carbonization, burning and other "damage" to the material. For example, claim 1 recites a method of using a laser, including "…a threshold speed below which ***at least one of carbonization, undesired burn through or undesired melting of the material of the product will occur***…" '602 Patent, Claim 1 (emphasis added). Claim 53 recites a method of forming a discontinuous design on a material, including "…a threshold speed where the laser beam ***will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting, or burn-through of the material***…." *Id.*, claim 53 (emphasis added). And Claim 93 recites a method of forming a pattern on fabric material, including a "critical operating

speed being one where a laser beam forms a desired pattern on said material ***without damaging the material in an undesired way***." *Id.*, claim 93 (emphasis added).[5]

What remains unclear based on the intrinsic evidence, however, is what, exactly, constitute these "undesired" and "damaging" effects. Indeed, the patent itself suggests that at least some damage to the fabric is both intended and *desired*. The Detailed Description of the Preferred Embodiment states that the "designs are formed by impingement of the laser beam on the surface of the thin fabric or leather. The laser beam destroys or changes a small portion of the material or dye . . . . ***The laser beam can form a design on the material by destroying, melting, shrinking, rumpling, crumpling, creping, watering, or crimping the material***." '602 Patent, Col. 6:9-19 (emphasis added).

This inconsistency even appears within the claims. For example, claim 99 requires determining "a radiation source power and speed of movement of an output of radiation source over the material that will cause a desired structural change without undesired damage to the material." *Id.*, claim 99. As explained by Dr. Cole, however, a person of ordinary skill in the art would understand that the claimed "desired structural change" is a desired form of damage to the material. Cole Report, ¶¶ 55-57. Yet the very same claim element limits the scope of the claim to causing such damage "*without* **undesired** *damage*." '602 Patent, claim 99. Again, however, the patent is silent as to what, exactly, constitutes "undesired damage."

The internal inconsistencies within the '602 Patent, its specification and prosecution history confirm Dr. Cole's opinion that one with ordinary skill in the art would understand the terms "undesired" and "undesirable" damage to be determined solely by individual opinion. The

[5] Claims 53 and 93 of the '602 Patent are not asserted claims. The use of language in the patent as a whole, however, is relevant to the interpretation of the meaning of individual claim terms. *Phillips v. AWH Corp.*, 415 F.3d 1303, 1313 (Fed. Cir. 2005) (*en banc*) ("Importantly, the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification").

intrinsic evidence provides no objective standard for determining what kind of damage is intended and desired, versus what kind of damage to the material is "undesired." For these reasons, the asserted claims of the '602 Patent fail to provide one of skill in the art with any certainty about the scope of the claimed invention. *Nautilus*, 134 S. Ct. at 2128 (noting that a patent must be precise enough to afford clear notice of what is claimed, thereby "appris[ing] the public of what is still open to them").

3. The Examples in the '602 Patent Do Not Change the Subjective Nature Of What Is – Or What Might Not Be – "Undesired."

Complainants' expert, Dr. Pfefforkorn, suggests that the '602 Patent contains "objective direction" for determining what might constitute the "undesired" effects that the asserted claims of the '602 Patent instruct a user to avoid. Pfefferkorn Report, ¶¶ 55-59. In support of this opinion, Dr. Pfefferkorn points to the definitions of "threshold speed" and "critical operating speed," and to Tables 1 and 2 in the specification. *Id.*, ¶¶ 56-58. These, Dr. Pfefferkorn suggests, are sufficient to provide "direction to one of ordinary skill in the art as to the objective factors that will result in the intended level of carbonization for a given material in Tables 1 and 2." *Id.*, ¶ 59.

As a preliminary matter, this is precisely the argument that was rejected in *Prolifiq*, finding that claims containing the term "differently versioned" were invalid as indefinite. Relying on Federal Circuit's analysis of purely subjective claim terms in the *Datamize* opinion, the district court in *Prolifiq* found that just because the specifications of the patents at-issue in that case contained examples did "not mean that the patents provide an objective standard for determining what is meant by 'differently versioned.'" *Prolifiq*, 2014 U.S. Dist. LEXIS 108630 at *20 (applying post-*Nautilus* law).

> For example, the claims in *Datamize* could not have been saved simply by providing examples in the specification of items that are "aesthetically pleasing,"

> such as a rose or a sunset. Providing examples of things that are generally considered "aesthetically pleasing" does not change the subjective nature of the term "aesthetically pleasing."

Id. Further, the court specified that the scope of a claim is determined not just by what is included, but by what is ***not*** included:

> [T]o determine the scope of a claim, a person skilled in the art must know not only what falls inside the scope of the claim term, but also what falls outside of it. This knowledge provides a person skilled in the art with the boundaries of the invention. Indeed, to provide a person of skill in the art with the boundaries of the claims at issue, that person must know both when something is a differently versioned digital content element and when something is not a differently versioned content element. Stating examples of differently versioned digital content elements only provides information about when something is a differently versioned digital content element, but it does not provide information about when something is not a differently versioned content element. ***Thus, examples do not necessarily provide information about what falls outside the scope of the claims.***

Id. at 20-21 (emphasis added). The examples in the '602 fail to provide sufficient definition to what might be "undesired" for exactly the same reasons.

The '602 Patent does provide broad definitions of "threshold speed" and "Critical Operating Speed." These definitions more or less suggest there is some sort of "goldilocks" speed at which a laser may be operated that is somewhere between a speed that is so slow that "the laser beam fully penetrates the fabric and results in carbonization, complete melting, and/or burn-through" ('602 Patent, Col. 3:45-48, defining "Threshold Speed") and a speed that is so fast that a "propensity to not form a design on the fabric increases" ('602 Patent, Col. 4:29-33). It is this "goldilocks" speed – not too slow, and not too fast – that the patent defines as a "Critical Operating Speed." '602 Patent, Col. 4:29-33.

The '602 Patent also provides some examples of speeds for some fabrics, which the patent suggests – within a certain degree of error – might fall within the range of these defined speeds. '602 Patent, Tables 1 and 2. For reference, Table 1 is recreated in full below:

TABLE I

Process Operating Speed for Laser Design on General Fabrics and Leathers

Material (Woven, Nonwoven or Knitted)	Design	Operating Speed (m/sec)
Cotton	SC	0.08–1.5
Rayon	SC	0.08–1.5
Acetate	SC	0.08–1.5
Nylon	SC, FP	1.0–1.5
Artificial Fiber	SC, FP	0.08–1.5
Half Wool	SC, R	1.0–1.5
Wool	SC, R	0.01–1.0
Flax	SC, R	0.05–1.5
Natural Silk	SC	1.0–1.5
Artificial Silk	SC, FP	1.0–1.5
Mixed Fiber Fabric	SC, FP, R	0.01–1.5
Chemical Fiber Fabric	SC, FP, R	0.01–1.0
Polyamide, Polyamide Chloride	SC, FP	0.01–1.0
Lavsan	SC	0.01–1.0
Pig Leather	SC, FP, R	0.01–1.0
Kid Leather	SC, FP, R	0.01–1.0
Box Calf Leather	SC, FP, R	0.01–1.0
Chamois Leather	SC, FP, R	0.01–1.0
Artificial Leather	SC, FP, R	0.01–1.0

Design Key:
SC = Single Color,
FP = Full Penetrating,
R = Relief

’602 Patent, Col. 4:1-28. This list and these definitions are the sum total of what Dr. Pfefferkorn suggests contain the information necessary for a person of ordinary skill to determine what is “undesired.”

What is notable is what information is not included in the specification. The list of fabrics included in the examples is obviously far from exhaustive – but the patent fails to provide any further explanation as to what the “goldilocks” speeds might be for any other fabrics. Nowhere in the definitions or tables to which Dr. Pfefferkorn points do the inventors define what is “undesired.” Nowhere is it explained what “designs” were purportedly created in the examples given in the Tables – or whether those designs, and those designs alone, constitute what might be “desired.” The patent never suggests that the ranges in Tables 1 and 2 are the ones that are used to obtain “desirable” results – or, conversely, whether straying outside of those ranges would result in something that is “undesired.” The claims in no way refer to any information contained in Tables 1 and 2, instead instructing a user to avoid something that is “undesired.” And Complainants, themselves, have never suggested that what is – or is not – included in the scope of “undesirable” effects that the claims require a user to avoid is limited to

speeds outside of those listed in Tables 1 and 2. Instead, Complainants merely suggest that these are examples, and that the "plain and ordinary meaning" of what is "undesired" should be applied to define the scope of the asserted claims.

Even reading the specification in the manner suggested by the Complainants, the scope of the claims still does not appear to be limited in any way, and more or less amounts to pointing a laser at something, and if you achieve what you want to, you fall within the scope of claims. As a matter of law, that is simply not sufficient to meet the bar definiteness required under 35 U.S.C. § 112 ¶ 2. Accordingly, H&M respectfully requests summary determination that claims 1, 14, 15, 73, 83, 85, 99, 112, 120, 122-124 and 141-143 of the '602 Patent are invalid as indefinite under 35 U.S.C. §112, ¶ 2.

B. **The "Undesirably Damage" Claim Term In Claims 2 and 4 Of The '972 Patent Is Subjective, And Is Indefinite Under Section 112, ¶ 2.**

Claim 2 of the '972 Patent uses language similar to the "undesirable" terms in the '602 Patent described above, and is indefinite for the same reasons. Claim 2 is a dependent claim directed to a method including "a plurality of said effective applied power levels are values which do not **undesirably damage** a material." '972 Patent, claim 2. Claim 4 depends on claim 2, adding only that the material used for the claimed method is denim. '972 Patent, claim 4.

1. The '972 Patent Leaves the Scope of What Is Included in the Claim Term "Undesirably Damage" Solely to the Subjective Determination of the User.

Much like the similar language used in the '602 Patent, the phrase "undesirably damage" does not appear in the specification of the '972 Patent, and what is or is not "undesirable" is entirely subjective in nature. Cole Report, ¶ 123. And, like the '602 Patent, the specification of the '972 Patent discusses potentially damaging effects to materials that appear to be both intended and unintended. *Compare* '972 Patent at Col. 3:43-44 (discussing "undesirably

burning, punching through or otherwise harming the textile material") with Col. 7:3-5 ("higher EDPUTs may be associated with more aggressive abrasion patterns including fraying…"). However, the '972 Patent offers no further clarity about the definition of "damage" as that term is used in claim 2.

The specification of the '972 Patent explains that "[t]he energy from the laser changes the look of the textile material without undesirably burning, punching through or otherwise harming the textile material. The basic operations of applying energy from a laser are described in U.S. Patent No. 5,990,444." '972 Patent, Col. 3:41-46. The specification goes on to explain that:

> The EDPUT is of sufficient magnitude to fray the denim so that individual threads are exposed or actual holes are provided in the denim. *This goes against the teaching in the above '444 patent*, which teaches that punch through of the material is undesired. The specific 'fraying' effect, provides enough EPDUT to intentionally cause damage to the material, however in a controllable and desired fashion.

Id., Col. 12:15-23 (emphasis added). The specification further explains that the laser used in the invention had been used in the prior art for cutting operations, and "[t]he expectation is that these higher power lasers would unintentionally damage the material. However, by adjusting the EDPUT, higher power lasers can safely be used." *Id.*, Col. 13:1-13:4.[6] Thus, the patent contemplates that some potentially damaging effects to materials are intentional – but others are, apparently, unintentional.

As Dr. Cole explains (and as not disputed by Dr. Pfefferkorn), "damage" does not have a single meaning to one of ordinary skill in the art. Cole Report, ¶¶ 55, 126; Pfefferkorn Report,

---

[6] As Dr. Cole explains, it is unclear how, if at all, the apparently intentional "damaging" effects described in the '972 Patent differ from claim language from an earlier filed patent by the same inventors, which also describes some intentional effects that may – or may not – constitute undesirable "damage." Cole Report, ¶¶ 133-134. For example, the earlier filed patent, U.S. Patent No. 5,990,444, also suggests that partial or complete carbonization and/or burnthrough is intended. '444 Patent, Col. 18:14-17. The '444 Patent also contemplates a "frayed look." *Id.*, Col. 1:16-22. It is unclear how these kinds of effects are distinct from those described – often with the same terminology – in the '972 Patent, filed years after the application leading to the '444 Patent.

¶¶ 79-85). It is possible that "burning," "punching through," and "fraying" – words that are used in the specification of the '972 Patent – may all fall within the broader meaning of the term "damage" as used in the '972 Patent. However, the patent does not distinguish or otherwise define when such damage (whether intentional or not) might be "desired" or when such damage would fall within the scope of "undesirably damage" as recited in claim 2. Cole Report, ¶ 127.

As one example, the specification of the '972 Patent describes worn looks that can be produced using the patented method, including "abrasion effects which simulate the look of a worn garment, whisker effects, frayed effects, as well as any other effect which is produced on a garment or other product made from a textile material and which makes the textile material look more like a used textile material." '972 Patent, Col. 3:30-35. According to the specification, this is accomplished because "[t]he applied energy from the laser changes the look of the textile material without undesirably burning, punching through, or otherwise harming the textile material." *Id.*, Col. 3:40-44.

However, the '972 Patent provides no details or objective way to measure at what point a laser may – or may not – be "undesirably damaging" a material during this process of using a laser to simulate a "worn look." Rather, the '972 Patent explicitly states that EDPUT control is "infinite and can vary a few percent to several thousand percent along each scanned line from one scanned line to another." *Id.*, Col. 7:13-16. As Dr. Cole confirms, an "infinite" number of options does not provide one with skill in the art with sufficient guidance on which subset of those options may fall within the scope of the "undesirably damage" limitation in Claim 2. Cole Report, ¶ 129. Claim 2 provides no further guidance, reciting only "a plurality of said effective applied power levels" that are "values that do not undesirably damage a material." '972 Patent, claim 2.

A patent that describes possibly damaging effects to material as being both potentially intended and unintended, explicitly discloses an "infinite" number of options for achieving those effects, and provides no further guidance as to what subset of those options may result in "undesirably damaging" a material, does not provide a person of skill in the art with any certainty as to what would fall within – or what would be outside – the scope of claim 2. Cole Report, ¶ 132. This failure to provide any guidance as to what constitutes "undesirable damage" falls far short of the "zone of certainty" required under *Nautilus*. *See Nautilus*, 134 S. Ct. at 2128.

2. The Examples in the ’972 Patent Do Not Change the Subjective Nature Of What Is – Or What Might Not Be – "Undesired."

Similar to the ’602 Patent, Complainants' expert again suggests that the ’972 Patent contains "a variety of objective parameters to provide an objective indication as to what parameters to control and settings to utilize to result in desired levels of damage (*i.e.*, the level of 'damage' necessary to create the intended effect or graphic.)" Pfefferkorn Report, ¶¶ 81-85. In support of this opinion, Dr. Pfefferkorn points to the discussions in the specification of laser parameters, and to tables 1-4 in the ’972 Patent. *Id.* These, Dr. Pfefferkorn suggests, are sufficient to provide "objective direction to one of ordinary skill in the art as to what constitutes 'undesirable damage.'" *Id.*, ¶ 85. For the same reasons discussed with respect to the "undesired" and "undesirably" claim terms in the ’602 Patent, these examples are not sufficient to meet the definiteness requirement in 35 U.S.C. § 112 ¶ 2.

The ’972 Patent does discuss operating parameters, as Dr. Pfefferkorn suggests. And, as Dr. Pfefferkorn suggests, it also includes some examples contained in tables, such as a list of EDPUT values in Table 1. This table is recreated below:

TABLE I

EDPUT Calculations for a Scanned Line

	Power (watts)	Spot (mm)	Area (mm2)	Speed mm/sec	EDPUT watts-sec/mm3
Scan #1:					
Start of Scan	150	0.30	0.0707	25,000	0.08
First Section of Scan	190	0.30	0.0707	25,000	0.11
First Quarter of Scan	225	0.30	0.0707	25,000	0.13
Second Quarter of Scan	250	0.30	0.0707	25,000	0.14
Middle of Scan	250	0.30	0.0707	25,000	0.14
Third Quarter of Scan	225	0.30	0.0707	25,000	0.13
Fourth Quarter of Scan	190	0.30	0.0707	25,000	0.11
End of Scan	150	0.30	0.0707	25,000	0.14
Scan #2:					
Start of Scan	50	0.30	0.0707	50,000	0.01
First Section of Scan	500	0.30	0.0707	50,000	0.14
First Quarter of Scan	800	0.30	0.0707	50,000	0.22
Second Quarter of Scan	1000	0.30	0.0707	50,000	0.28
Middle of Scan	1000	0.30	0.0707	50,000	0.28
Third Quarter of Scan	800	0.30	0.0707	50,000	0.22
Fourth Quarter of Scan	500	0.30	0.0707	50,000	0.14
End of Scan	300	0.30	0.0707	50,000	0.08
Scan #3:					
Start of Scan	50	0.30	0.0707	10,000	0.07
First Section of Scan	300	0.30	0.0707	10,000	0.42
First Quarter of Scan	500	0.30	0.0707	10,000	0.71
Second Quarter of Scan	1000	0.30	0.0707	10,000	1.41
Middle of Scan	1000	0.30	0.0707	10,000	1.41
Third Quarter of Scan	500	0.30	0.0707	10,000	0.71
Fourth Quarter of Scan	300	0.30	0.0707	10,000	0.42
End of Scan	50	0.30	0.0707	10,000	0.07

’972 Patent, Col. 6:20-62. However, the inventors explicitly declined to limit the scope of their claims to what is included in these tables. In fact, the EDPUT values in Table 1 are the very ones that the inventors stated “***can increase by any desired amount***.” ’972 Patent, Col. 7:10-11 (emphasis added). And it is in reference to the values contained in this very table that the inventors further stated, “[t]he EDPUT control ***is thus infinite*** and can vary a few percent to several thousand percent along each scanned line and from one scanned line to another.” ’972

Patent, Col. 7:13-15 (emphasis added). As set forth above and noted by Dr. Cole, a patent that explicitly discloses an “infinite” number of options, and provides no further guidance as to what subset of those options may result in “undesirably damaging” a material, does *not* provide a person of skill in the art with any certainty as to what would fall within – or what would be outside – the scope of the claims.

Once again, taken as a whole, the scope of what Complainants suggest their claims cover does not appear to be limited in any way, and more or less amounts to pointing a laser at something, such that if you achieve what you want to, you fall within the scope of claims. As a matter of law, that is simply not sufficient to meet the bar definiteness required under 35 U.S.C. § 112 ¶ 2. *See e.g.*, *Prolifiq*, 2014 U.S. Dist. LEXIS 108630 at *20 (noting that, to determine the scope of a claim, “a person skilled in the art must know not only what falls inside the scope of the claim term, but also what falls outside of it,” and providing examples does not necessary change the subjective nature of a claim term). Accordingly, H&M respectfully requests summary determination that claims 1, 14, 15, 73, 83, 85, 99, 112, 120, 122-124 and 141-143 of the ‘602 Patent are invalid as indefinite under 35 U.S.C. §112, ¶ 2.

Accordingly, H&M respectfully requests summary determination that Claims 2 and 4 are invalid as indefinite under 35 U.S.C. § 112, ¶ 2.

V. CLAIM 112 OF THE ‘602 PATENT IS INDEFINITE, AS IT INCLUDES AN ELEMENT THAT RELIES ON THE SUBJECTIVE AESTHETIC DETERMINATION OF A USER AS TO WHAT IS “IMPERFECT.”

Independent claim 112 is directed to a “method for producing a design on a material, comprising: . . . determining a critical parameter for said beam of radiation on said material based on characteristics of the material being used, and based on a determined maximum speed for the material being used at which less-than-desired change will be caused to said material, resulting in an ***imperfect pattern*** being formed on said material.” ‘602 Patent, Claim 112

(emphasis added). The term "imperfect pattern" is indefinite. This term only appears in the claims, and it is not discussed elsewhere in the specification or file history. Cole Report, ¶¶ 59-62. There is no explicit or implicit guidance in the context of those claims, the specification, or the file history regarding what constitutes an "imperfect pattern," or how one can create or avoid creating an "imperfect pattern." *Id*. "Imperfect pattern," moreover, has no plain and ordinary meaning to one of ordinary skill in the art. *Id.*, ¶ 59. Accordingly, the intrinsic evidence leaves "imperfect pattern" as an abstract term that is susceptible to multiple interpretations.

A pattern can be "imperfect," for example, if it does not exactly match a model pattern or template, if it lacks symmetry, if its repeating units are not identical, if it is too light or too dark, if it contains or omits characteristics in a way that is not intended or expected, if the accuracy of the replicated pattern varies across the pattern (*e.g.*, less accurate around the edges), or if the color is inconsistent across the pattern. Cole Report, ¶ 63. In light of these contending definitions, the term "imperfect pattern" is indefinite under the *Nautilus* standard because it "fail[s] to inform, with reasonable certainty, those skilled in the art about the scope of the invention. *Nautilus*, 134 S. Ct. at 2124.

Furthermore, the term "*imperfect* pattern" is also indefinite because the '602 Patent fails to disclose the requisite objective boundary to define the scope of this subjective term. *Interval Licensing*, 766 F.3d at 1371 ("The claims, when read in light of the specification and the prosecution history, must provide objective boundaries for those of skill in the art"). Instead, as Dr. Pfefferkorn himself agrees, what is "imperfect" again is left solely to the subjective determination by the user. Pfefferkorn Report, ¶ 96 ("an imperfect pattern is a pattern that is formed when the laser is operated at a speed that fails to create the intended design on the material"). Without any objective guidelines or defined thresholds regarding what types of

imperfections are at issue or the degree of imperfections that render a pattern "imperfect," the scope of this term is subject to change based solely on the aesthetic determination of the eye of the beholder. Cole Report, ¶ 64. Therefore, "imperfect pattern" is indefinite because it "leav[es] the skilled artisan to consult the unpredictable vagaries of any one person's opinion." *Interval Licensing*, 766 F.3d at 1373; *see also, Datamize LLC*, 417 F. 3d at 1350 (to be definite, a claim term requires an objective anchor, and cannot "depend solely on the unrestrained, subjective opinion of a particular individual purportedly practicing the invention").

Accordingly, H&M respectfully requests summary determination that claim 112 the '602 Patent is invalid as indefinite under 35 U.S.C. § 112 ¶ 2.

VI. ALL ASSERTED CLAIMS IN THE '972 PATENT THAT RECITE AN ELEMENT THAT IS COINED BY THE INVENTORS, YET WHOLLY UNDEFINED, ARE INDEFINITE.

Each of claims 1, 2, 4-6, 11, 12, 17-19, 63, 64, 72, 77, and 94-95 of the '972 Patent recite a variation of an entirely made up term "effective applied power, "effective applied power levels," "effective applied energy," or "effective applied energy value." However, while the patentee clearly intended to coin these phrases, the '972 Patent describes these terms in the specification only by referring to numerous irreconcilable parameters – none of which can be said to be "energy" or "power." '972 Patent, *e.g.*, 3:47-64, 4:8-21, 4:24-5:14, Table I & II. The failure of the patentee to provide clear definition to terms that he coined, and the incoherent manner in which these made up terms are otherwise described in the specification of the '972 Patent, renders these terms wholly ambiguous and without clear definition to one of ordinary skill in the art. *See In re Paulsen*, 30 F. 3d 1475, 1480 (Fed. Cir. 1994) (inventor may define specific terms used to describe his invention, but must do so "with reasonable clarity, deliberateness, and precision" and, if done, must "set out his uncommon definition in some manner within the patent disclosures so as to give one of ordinary skill in the art notice of the

change in meaning") (internal citations omitted).

A. <u>Energy And Power Are Fundamentally Different.</u>

"***Energy***" is generally defined as the ability to do work, and is expressed in "Joules" (J). Cole Report at ¶ 99. In laser applications such as those at issue in this Investigation, laser energy is a theoretical maximum energy that can be transformed into heat if all of the energy were to be absorbed by the material to which the laser is being applied. In the real world, however, it is understood by those with ordinary skill in the art that other factors diminish the amount of laser energy actually absorbed, including the material being laser-treated itself. *Id.*, ¶¶ 100-101. Units of energy are known as "Joules." Id., ¶ 99. 1 Joule = 1 Watt second. *Id.* In other words, 1 Joule is the equivalent to the power of one watt sustained for one second.

"***Power***," on the other hand, is generally defined as the ***rate*** of energy, and is expressed in Watts (W). *Id.*, ¶ 102. Thus, while laser *energy* is transformed into heat, the *power* of a laser reflects the rate of heating. *Id.*, ¶ 103. In theory, a laser's power can be calculated from laser energy divided by exposure time. But power can also refer to the output power of the laser, which is an adjustable laser parameter rather than a calculated value. *Id.*

Thus, while energy and power are related, they are fundamentally different concepts, and are calculated and measured in fundamentally different ways. *Id.*, ¶ 103. For example, when operated at a higher power, a hypothetical laser would impact a surface for period of time to produce a certain amount of heat. If the same hypothetical laser was operated at a lower power, it would need to be exposed to the surface of the material for a relatively longer time to produce the same amount of heat. Both examples delivered the same amount of energy, but were operated with different power. *Id.*, ¶ 103.

B. The Scope of "Effective Applied Energy" Is Indefinite.

"Effective applied energy" is not a term of art, and its only use in the context of lasers is in the '972 Patent's specification. *Id.*, ¶ 104. The term was not discussed in the prosecution history.

Out of context, "effective applied energy" should logically be bound to the understood meaning of "energy." But the '972 Patent uses "effective applied energy" inconsistently with the well understood meaning of "energy." For example, claims 19, 43, 55, 82, 87, and 94 (of which, only 19 and 94 are asserted against H&M) specify that that effective applied energy is "one of an energy density per unit time [EDPUT], power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser." This creates a problem because:

- EDPUT is a term coined by the applicant, expressed in watt-sec/mm^3, and is roughly equivalent to *power density*;
- Power of a laser is the *rate of energy* being emitted from the laser;
- Duty cycle is the *percentage of time that the laser is emitting light in each pulse of a pulsed laser*;
- Speed is the distance per unit *time that the laser moves*; and
- Distance is the *distance between the laser and the surface*.

None of these are energy, and each is fundamentally different from the other. Accepting all of these as definitions of "effective applied energy" means that this one term could be expressed in at least watt-sec/mm^3, watts, a percentage, m/s, or m. This makes no sense.

The specification does not resolve the claims' conflicting definitions because it contains the same conflicts plus at least one more. Like the claims, it equates effective applied energy with EDPUT, scan line speed, power level, speed level, duty cycle level, and distance. '972 Patent, Col. 3:47-50, 3:57-60, 4:8-12, 4:17-21, 4:24-5:14. The specification further defines "effective applied energy" as "***effective applied power*** being applied in multiple sessions or

times." *Id.*, Col. 3:62-64 (emphasis added). As explained below, "effective applied power" is also indefinite. But even if "effective applied energy" simply meant "power" — and it cannot per its definition in the specification — ***power is not energy***.

The definiteness requirement as clarified by the Supreme Court "mandates clarity." *Nautilus*, 134 S.Ct. at 2129. Claims are indefinite where a person of ordinary skill in the art, at the time the patent was filed, cannot reasonably determine the claim scope in light of the specification and prosecution history. *Id.* That is the situation here, where the claim and specification use a coined term — "effective applied energy" — to mean various unrelated and conflicting measurements, nearly all of which are ***not*** energy.[7] Accordingly, H&M respectfully requests summary determination that claims 19, 63, 72, 77, and 93-95 are invalid under 35 U.S.C. 112 ¶ 2.

C. <u>The Scope of "Effective Applied Power" Is Indefinite.</u>

"Effective applied power" is another coined term whose only use regarding lasers is in the '972 Patent's specification. Cole Report, ¶ 110. Similar to "effective applied energy," the claims and specification use the term to mean something other than power, but fail to teach what "effective applied power" actually is. For example:

- Claim 16 recites that "effective applied power" is changed by "changing an output size of a laser beam," but power does not depend on beam size and only the *area* being treated is affected by beam size. *Id.*, ¶ 112.
- Claim 89 states that "effective applied power" is changed "by making multiple passes of laser scans along specific segments of the pattern, each of said passes being carried out at constant power, speed and laser distance." Confusingly, the

---

[7] The specification lists a single example where "effective applied energy" is used consistent with energy: the "***concept*** of effective applied energy . . . ***includes*** the amount of energy that is effectively applied to an area of a material."'972 Patent, Col. 3:53-56 (emphasis added). And in the next breath it expands the "concept" to include many non-energy measurements: "effective applied energy" includes "EDPUT," and "changing scan line speed, power level or speed level or duty cycles level of the laser," changing the distance of the laser and material, and "effective applied power being applied in multiple passes or times." *Id.*, Col. 3:57-63.

> specification uses this same language to define "effective applied ***energy***." '972 Patent, Col. 3:62-64; Cole Report, ¶ 112. And effective applied energy, as explained above, can also be "one of an energy density per unit time [EDPUT], power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser." '972 Patent, claims 19, 43, 55, 82, 87, and 94.

The specification also uses "effective applied power" in ways that simultaneously encompass and exclude **output power**. *Id.* at 4:24-26, 4:63-64, claims 1, 8, 9, 44, 68, 76, 78 and 89. According to Claim 1, "energy density per unit time . . . depends on . . . effective applied power," and the specification makes clear that EDPUT depends on output power. *Id.,* Col. 4:24-26, 4:62-64. This suggests that "effective applied power" equals output power. However, claim 89 states that "effective applied power" **changes** across multiple scans with **constant** power, which does not follow if "effective applied power" encompasses output power. Furthermore, "output power" and "effective applied power" are used independently and *differently* within particular claims, so "effective applied power" cannot mean output power. *Id.,* claims 8, 9, 44, 67, 68 and 78.

The '972 Patent's inconsistent and conflicting use of "effective applied power" means that a person of ordinary skill in the art, at the time the patent was filed, could not reasonably determine the claim scope in light of the specification and prosecution history. *Nautilus,* 134 S. Ct. at 2129. Because no definition of "effective applied power" can reconcile all the inconsistent uses of the term, H&M respectfully requests summary determination that claims 1-2, 4-6, 11-12, 17-18, and 64 are indefinite under 35 U.S.C. 112, ¶ 2.

VII. ALL ASSERTED CLAIMS OF THE '505 PATENT ARE INVALID AS INDEFINITE, AS THE CLAIM TERM "MATHEMATICAL OPERATION" IS LIMITLESS.

The claim term "mathematical operation" is indefinite for lack of discernible meaning under § 112, ¶ 2. Claim 1 recites "A method, comprising: allowing a user to enter and/or change each of a plurality of different parameters; carrying out a mathematical operation based on said

parameters to form values which are individualized for each of a plurality of areas; and using said values to control a laser to change a look of a textile material according to said values." '505 Patent, Col. 10:59-67. Claim 49 similarly uses "mathematical operation." *Id.*, Col. 13:17-28. Claims 50 and 51 of the '505 Patent depend on claim 49.

Neither the patent nor its file history specify the claimed "mathematical operation." Cole Report, ¶ 89. The phrase "mathematical operation" appears only once in the patent specification:

> relationship, or can be totally random. **1910** shows a mathematical operation of
>
> $$\frac{\frac{Z1}{W1} + \frac{z2}{w2} + \frac{z3}{w3} \ldots + \frac{zn}{wn}}{N}$$
>
> can take any of the values z_n and weight them by any desired amount w_n, and take an average of those values.

Id.; '505 Patent, Col. 6:53-61. As shown above, the disclosed mathematical operation appears in a sentence that is grammatically incorrect, adding even more ambiguity to the claimed "mathematical operation." *Id.* Several dependent claims identify functions that the claimed mathematical operation might "include" or "use," such as "cellular automata" or a "modulus function." '505 Patent, claims 2-13; Cole Report, ¶ 90. But explaining that a mathematical operation may include or use certain functions does not define the mathematical operation itself. Cole Report, ¶ 90.

"Mathematical operation" was substantively discussed only once during prosecution. Complaint, App. G, '505 Patent File History, Amendment dated 1/9/2003 (EDIS Doc. ID No. 540354 (Aug. 18, 2014) (attached to public version of complaint)). In that response, the inventor attempted to distinguish an earlier filed patent, the '444 Patent, from the application leading to the '505 Patent by arguing that "nothing in [the Costin '444 Patent] teaches or suggests anything about using a mathematical operation to form individualized values or to form Fractal items, as

currently claimed." *Id*., p. 21. The inventor further argued: "The '444 Patent teaches nothing about a mathematical operation based on input parameters to form the pattern." *Id.*, pp. 22-23.

From these disclosures, a skilled artisan could, at best, glean that the "mathematical operation" is some operation that produces individualized values or fractal items based on input parameters to form some pattern or parameters. Cole Report, ¶ 93. But what that operation is, specifically, is not disclosed in the patent or prosecution history.

At the time the '505 Patent was filed, there was no generally accepted understanding of what constitutes a "mathematical operation" as claimed in the patent. *Id.*, ¶ 91. The Oxford English Dictionary defines "operation" as "[a] process in which a number, quantity, expression, etc. is altered or manipulated according to set formal rules, such as those of addition, multiplication, and differentiation." *Id.*, ¶ 94. Applying that definition, it is clear that not every mathematical operation could be employed in the context of the claimed invention. *Id.*, ¶ 95. For example, some operations would result in complete vaporization of the textile. *Id.* Other operations would not effectively change the look of the textile as desired. *Id.*

Given that there is an unlimited number of possible "mathematical operations" that could be employed in the context of the invention, without direction as to what specific mathematical operations may be contemplated (other than the single example disclosed in the specification), the patent fails to afford clear notice of what is claimed. *Id.*, ¶ 96. Based on the lack of disclosure in the patent and file history, and applying the common definition of "mathematical operation," persons of ordinary skill in the art would not be able to ascertain which mathematical operations would infringe the claims of the '505 Patent that contain that phrase. *Id.*

Accordingly, H&M respectfully requests summary determination that independent claims 1 and 49, and claims 50 and 51 of the '505 Patent (which depend on claim 49), are invalid as

indefinite under 35 U.S.C. § 112 ¶ 2.

Dated: September 1, 2015

Respectfully Submitted:

/s/ Staci Jennifer Riordan
Staci Jennifer Riordan
Neal J. Gauger
NIXON PEABODY LLP
Gas Company Tower
555 W. Fifth Street, 46th Floor
Los Angeles, CA 90013-1010
Telephone: 213-629-6000
Facsimile: 213-629-6001

Shawn G. Hansen
Jennifer Hayes
NIXON PEABODY LLP
2 Palo Alto Square, Suite 500
3000 El Camino Real
Palo Alto, CA 94306-2106
Telephone: 650-320-7700
Facsimile: 650-320-7701

Maia H. Harris
Michelle A. Flores
Charles Dell'Anno
NIXON PEABODY LLP
100 Summer Street
Boston, MA 02110-2131
Telephone: 617-345-1000
Facsimile: 617-345-1300

Counsel for Respondents
H & M Hennes & Mauritz L.P. and
H & M Hennes & Mauritz AB

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing document was served to the parties, in the manner indicated below, on September 1, 2015.

The Honorable Lisa R. Barton Secretary to the Commission U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 112 Washington, DC 20436	☒ **VIA ELECTRONIC FILING**
The Honorable MaryJoan McNamara Administrative Law Judge U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 317 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (to sarah.zimmerman@usitc.gov) ☒ **VIA U.S. MAIL**
Peter Sawert, Esq. Commission Investigative Attorney Office of Unfair Import Investigations U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 401 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (peter.sawert@usitc.gov)
COUNSEL FOR COMPLAINANTS REVOLAZE, LLC AND TECHNOLINES, LLC	
Cindy S. Ahn SCHIFF HARDIN LLP 233 S. Wacker Drive Suite 6600 Chicago, IL 60606 Benoit Quarmby MOLOLAMKEN LLP 540 Madison Avenue New York, NY 10022 Elizabeth Koehn Global IP Law Group, LLC 233 South Wacker Drive, 92nd Floor Chicago, IL 20004	☒ **VIA ELECTRONIC MAIL** (Revolaze@mololamken.com) (Revolaze@giplg.com)
COUNSEL FOR RESPONDENT THE GAP, INC.	
Marcia H. Sundeen GOODWIN PROCTER LLP 901 New York Ave, NW Washington, DC 20001	☒ **VIA ELECTRONIC MAIL** (Msundeen@goodwinprocter.com) (DG-Goodwin_930@goodwinprocter.com)
Aimee Soucie KENYON & KENYON LLP 1500 K Street, N.W. Washington, DC 20005-1257	☒ **VIA ELECTRONIC MAIL** (GapITC@kenyon.com)

COUNSEL FOR RESPONDENT KOOS MANUFACTURING, INC.	
Brian K. Brookey TUCKER ELLIS LLP 515 South Flower Street, Forty Second Floor Los Angeles, CA 90071-2223	☒ **VIA ELECTRONIC MAIL** (KoosITC@tuckerellis.com)
COUNSEL FOR EROGLU GIYIM SANAYI TICARET A.S.	
Janine A. Carlan ARENT FOX LLP 1717 K Street, N.W. Washington, DC 20006-5344	☒ **VIA ELECTRONIC MAIL** (ITC-930-Eroglu@arentfox.com)

<u>/s/ Maia H. Harris</u>
NIXON PEABODY LLP

UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, DC

Honorable MaryJoan McNamara, Administrative Law Judge

In the Matter of CERTAIN LASER ABRADED DENIM GARMENTS	Investigation No. 337-TA-930

STATEMENT OF FACTS IN SUPPORT OF
H & M HENNES & MAURITZ L.P. AND H & M HENNES & MAURITZ AB'S MOTION
FOR SUMMARY DETERMINATION OF INVALIDITY OF
THE ASSERTED PATENTS ON THE BASIS OF INDEFINITENESS

Pursuant to Rule 210.18 and Ground Rule 3.4, Respondents H & M Hennes & Mauritz L.P. and H & M Hennes & Mauritz AB (collectively, "H&M"), by and through undersigned counsel, submit the following Statement of Facts in Support of its Motion for Summary Determination of Invalidity of The Asserted Patents on the Basis of Indefiniteness, over which H&M contends there is not genuine issue:

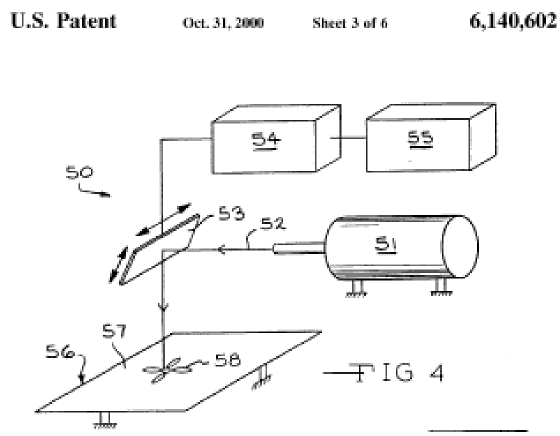
1. Three patents remain at-issue in this Investigation: U.S. Patent No. 6,140,602 ("the '602 Patent"), U.S. Patent No. 6,819,972 ("the '972 Patent"), and U.S. Patent No. 6,664,505 ("the '505 Patent") (the "Asserted Patents"). The Asserted Patents are respectively attached as Exhibits 1-3 to the *Memorandum and Points of Authorities in Support of H & M Hennes & Mauritz L.P. and H & M Hennes & Mauritz AB's Motion for Summary Determination of Invalidity of the Asserted Patents on the Basis of Indefiniteness*, filed contemporaneously herewith ("Memo").

2. The Asserted Patents contain 367 total claims. *See generally*, Asserted Patents, Memo Exhibits 1-3.

3. The purported inventions disclosed in each of the Asserted Patents generally

relate to methods of controlling a laser to form certain effects on materials, such as denim. *See generally*, Asserted Patents, Memo Exhibits 1-3.

4. The following figure is taken from the ’602 Patent:



Memo Exhibit 1, ’602 Patent, Figure 4.

5. As described by the inventors, “FIGS. 1 through 9 are schematic views of a laser method of forming designs on thin fabrics and leathers in accordance with this invention…FIG. 4 illustrates a method in which a mirror is moved to direct the laser beam onto the surface of the fabric.” Memo Exhibit 1, ’602 Patent, Col. 2:25-29, 2:39-41.

6. As described in the specification and claims of the ’602 Patent, the claimed method(s) recite the control of certain operating parameters to control the laser, such as speed. *See e.g.*, Memo Exhibit 1, ’602 Patent, Col. 1:54-59 (“The method uses a laser beam to slightly penetrate the surface of the product at a controlled specific speed. The laser beam is directed at the product either directly or through mirrors, shutters or lenses. The speed of the laser with beam relative to the surface of the product is controlled within a predetermined range”).

7. The parameters are controlled to transfer a design to fabrics while “overcoming the technical barriers of carbonization, complete melting and/or burn-through.” Memo Exhibit 1, ’602 Patent, Col. 2:1-2.

8. In most of the asserted claims of the ’602 Patent, the method involves determining and using a laser speed that is greater than a minimum speed (sometimes referred to as “threshold speed”) but below a maximum speed. *See e.g.*, Memo Exhibit 1, ’602 Patent, Claims 1, 14, 15, 73, 83, 85, 99, 112, 120-124, 141-143.

9. The threshold speed is a laser speed below which the laser will move too slowly relative to the material and cause what the claims call “undesired” effects on the material. *See e.g.*, Memo Exhibit 1, ’602 Patent, Col. 3:45-49, Claim 1.

10. The maximum speed is a laser speed above which the laser will move to quickly relative to the material and will not form what some of the claims recite as a “desired” change to the material. *See e.g.*, Memo Exhibit 1, ’602 Patent, Col. 3:47-51, Claim 1.

11. Claim 1 of the ’602 Patent is directed to “a method of using a laser for forming a design on a product,” comprising “determining … a threshold speed below which at least one of carbonization, undesired burn through or undesired melting of the material of the product will occur…” Memo Exhibit 1, ’602 Patent, Claim 1.

12. Claim 53 recites a method of forming a discontinuous design on a material, including “…a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting, or burn-through of the material….” Memo Exhibit 1, ’602 Patent, Claim 53.

13. Claim 93 of the ’602 Patent recites a method of forming a pattern on fabric material, including a “critical operating speed being one where a laser beam forms a desired pattern on said material without damaging the material in an undesired way.” Memo Exhibit 1, ’602 Patent, Claim 93.

14. Claim 99 of the ’602 Patent requires determining “a radiation source power and

speed of movement of an output of radiation source over the material that will cause a desired structural change without undesired damage to the material." Memo Exhibit 1, '602 Patent, Claim 99.

15. The terms "undesired" and "undesirably" also appear in claim 73 ("…determining, for said specific material, a threshold speed of scanning for said laser, below which undesired damage to the material will be caused…"), claim 112 ("…determined minimum operating speed for the material being used at which undesired damage to the material will be formed…"), claim 120 ("…to form a pattern in the material which changes the material without undesirably damaging the material…"), and claim 141 ("…causes a pattern which can be seen to be formed in the material without undesirably damaging the material…"). Memo Exhibit 1, '602 Patent, Claims 73, 112, 120, 141.

16. Claim 112 is directed to a "method for producing a design on a material, comprising: . . . determining a critical parameter for said beam of radiation on said material based on characteristics of the material being used, and based on a determined maximum speed for the material being used at which less-than-desired change will be caused to said material, resulting in an imperfect pattern being formed on said material." Memo Exhibit 1, '602 Patent, Claim 112.

17. The terms "undesired" and "undesirable" do not have generally accepted meanings to one of ordinary skill in the art. Memo Exhibit 7, *Opening Expert Report of Christine W. (Jarvis) Cole, Ph. D. on Claim Construction Issues*, December 19, 2014 ("Cole Report"), ¶ 51; Memo Exhibit 8, *Rebuttal Expert Report of Frank Pfefferkorn, Ph. D Regarding Claim Construction Issues*, January 16, 2015 ("Pfefferkorn Report") ¶¶ 52-59.

18. The terms "damage" and "damaging" do not have a single meaning to one with

ordinary skill in the art. Memo Exhibit 7, Cole Report, ¶ 55; Memo Exhibit 8, Pfefferkorn Report, ¶¶ 52-59.

19. The term "damage" appears nowhere in the specification of the '602 Patent. Memo Exhibit 1, '602 Patent.

20. The term "undesirable" appears only once in the '602 Patent, but is not used to modify the terms "burn through," "damage," or other effects referenced by the claims. It appears in the Background of the Specification describing prior art uses of lasers in the fabric industry:

> When such use was attempted, the laser beam caused carbonization, complete melting, and/or burn through at the point of contact. This resulted in complete penetration and the formation of **an undesirable hole or defect** in the fabric or leather.

Memo Exhibit 1, '602 Patent, Col. 1:35-40.

21. The specification of the '602 Patent states that the claimed invention (*i.e.*, the "specific identification and control of speed") provides "the keys to preventing carbonization, complete melting and/or burn-through of the fabric." Memo Exhibit 1, '602 Patent, Col. 3:37-40.

22. The specification of the '602 Patent states that "[i]t has been discovered that there is a Critical Operating Speed above which the propensity to not form a design on the fabric increases, and below which the propensity to cause burn-through, complete melting and/or carbonization increases." Memo Exhibit 1, '602 Patent, Col. 4:29-33.

23. The Detailed Description of the Preferred Embodiment of the '602 Patent states that the "designs are formed by impingement of the laser beam on the surface of the thin fabric or leather. The laser beam destroys or changes a small portion of the material or dye . . . . The laser beam can form a design on the material by destroying, melting, shrinking, rumpling,

crumpling, creping, watering, or crimping the material." Memo Exhibit 1, '602 Patent, Col. 6:9-19 .

24. In distinguishing over prior art cited by the Examiner, the Applicants amended their claims to add the "without undesireably [sic] damaging" claim terms in their April 27, 1997 Response.

> The inventor of the present invention recognized special operational parameters which allow a focused beam of radiation, such as a laser beam, to be used to form a design or pattern in the material without undesireably damaging the material. This is done by determining parameters of control for a specific material with specific characteristics. The preferred embodiment calls these parameters a critical operating speed. This is the speed that the laser beam must travel relative to the material being changed in order to form a pattern/design, but still avoid damage to the material.

Complaint, App. C, '602 File History, Response to Office Action dated 4/27/1997, p. 51 (EDIS Doc. ID No. 540354 (Aug. 18, 2014) (attached to public version of original complaint)).

25. The applicants further stated:

> As described above, an important realization of the present invention is the special parameters which allow a design to be formed on a product without damage to the product. There is nothing in the prior art references which teach or suggest how to form a pattern on the material without undesirably damaging the material.

Id., p. 52.

26. The Applicants further stated:

> Claim 1 has been amended herewith to recite elements of this method. An initial step requires determining, for a material being used, a maximum speed of said material relative to the laser for a given laser power that will result in a perceivable change being formed, and a threshold speed below which at least one of carbonization, undesired burn through or melting of the fabric will be caused. This has been found by the inventors to be crucial for forming the proper indicia on the material without burning.

Id., p. 53.

27. The ’505 Patent contains the following figure:

U.S. Patent Dec. 16, 2003 Sheet 1 of 22 US 6,664,505 B2

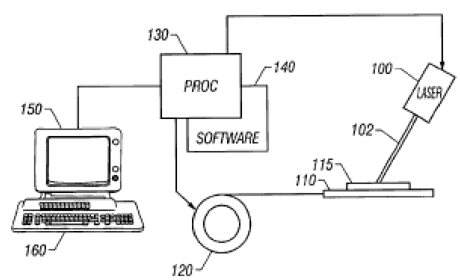


FIG. 1

Memo Exhibit 2, ’505 Patent, Figure 1, Col. 1:45-50 (“FIG. 1 shows a block diagram of the basic system of the present invention including the processor, and the marking device being a laser”).

28. According to the inventors, the ’505 Patent “teaches additional tools and techniques intended for controlling a laser to produce an output beam that changes the look of a specified garment or material in a new way,” this time using a “mathematically-based process.” Memo Exhibit 2, ’505 Patent, Col. 1:30-36.

29. The ’505 Patent specification describes controlling the laser, where the “user can interact with the effect selection by entering parameter values, modifying looks and producing a

final pattern to be written on to the material." Memo Exhibit 2, '505 Patent, Col. 2:60-63.

30. The method recited in each of the asserted claims of the '505 Patent involve performing what the claims call a "mathematical operation" based on input parameters to form "values which are individualized for each of a plurality of areas." Memo Exhibit 2, '505 Patent, Claims 1, 49-51. The method then involves using the formed values to control a laser to "change a look" of a textile material. *Id.*

31. Claim 1 of the '505 Patent recites "A method, comprising: allowing a user to enter and/or change each of a plurality of different parameters; carrying out a mathematical operation based on said parameters to form values which are individualized for each of a plurality of areas; and using said values to control a laser to change a look of a textile material according to said values." Memo Exhibit 2, '505 Patent, Col. 10:59-67.

32. Claim 49 of the '505 Patent recites the use of a "mathematical operation." Memo Exhibit 2, '505 Patent, Col. 13:17-28.

33. Claims 50 and 51 of the '505 Patent depend on claim 49. Memo Exhibit 2, '505 Patent, Clams 50 and 51.

34. The phrase "mathematical operation" appears only once in the specification of the '505 Patent:

> relationship, or can be totally random. **1910** shows a mathematical operation of
>
> $$\frac{\frac{Z1}{W1} + \frac{z2}{w2} + \frac{z3}{w3} \ldots + \frac{zn}{wn}}{N}$$
>
> can take any of the values z_n, and weight them by any desired amount w_n, and take an average of those values.

Memo Exhibit 2, '505 Patent, Col. 6:53-61.

35. "Mathematical operation" was substantively discussed only once during

prosecution. Complaint, App. G, ’505 Patent File History, Amendment dated 1/9/2003 (EDIS Doc. ID No. 540354 (Aug. 18, 2014) (attached to public version of complaint)). In that response, the inventor stated, “nothing in [the Costin ’444 Patent] teaches or suggests anything about using a mathematical operation to form individualized values or to form Fractal items, as currently claimed.” *Id*., p. 21. The inventor further stated: “The ’444 Patent teaches nothing about a mathematical operation based on input parameters to form the pattern.” *Id.*, pp. 22-23.

36. The ’972 Patent contains the following figure:

U.S. Patent Nov. 16, 2004 Sheet 1 of 13 US 6,819,972 B1

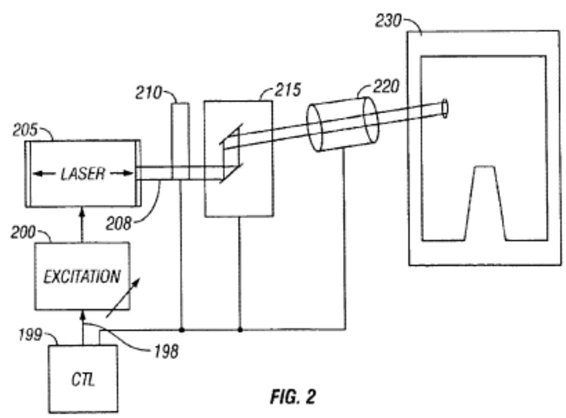


FIG. 2

Memo Exhibit 3, ’972 Patent, Figure 2, Col. 3:17 (“FIG. 2 shows a controllable lasing system”).

37. The inventors describe the inventions in the ‘972 Patent as “new laser scribing devices and techniques to simulate specified worn looks on fabrics and garments.” Memo Exhibit 3, ’972 Patent, Col. 2:42-45. “These worn looks can include abrasion effects which simulate the look of a worn garment, whisker effects, frayed effects.” *Id.*, Col. 3:30-32.

38. The inventors of the ’972 Patent state that they “introduce” a concept coined as “effective applied power” and/or “effective applied energy,” which is controlled such that it changes the look of textile materials. Memo Exhibit 3, ‘972 Patent, Col. 3:40-65.

39. According to the inventors, effective applied energy as used in the ’972 Patent

"includes the amount of energy that is effectively applied to an area of a material. That area can be any size or shape. The 'effective applied energy' can include EDPUT, but also includes changing scan line speed, power level or speed level or duty cycle level of the laser. It includes changing the distance of the laser to the material, which can defocus the laser, and thereby change the EDPUT. It also includes effective applied power being applied in multiple sessions or times, by applying multiple passes, *e.g.*, of fixed power etc. The effect is to apply more energy to some areas than to others." Memo Exhibit 3, '972 Patent, Col. 3:40-65.

40. The asserted claims of the '972 Patent generally involve controlling the laser by using stored information concerning an "effective applied power" or an "effective applied energy." *See e.g.*, Memo Exhibit 3, '972 Patent, Claims 1, 2, 4-6, 11, 12, 17-19, 63, 64, 72, 77, 78, 93-95. In some instances, the laser is controlled to form a pattern on the material (*see e.g.*, claims 1, 56, and 78), while in other instances the laser changes the color of the material (*see e.g.*, claims 72 and 92). In some instances, the claims methods involve storing information about "effective applied power levels" to be applied by a laser during its scan lines. *See* Memo Exhibit 3, '972 Patent, Claim 1.

41. In some instances, the methods recited in the asserted claims of the '972 Patent also involve controlling the scan lines by controlling an "energy density per unit time" that "depends on [the] effective applied power levels." *See e.g.*, *id.* And in some instances, the scan lines will have "levels of effective applied power which change within a single scan line." *Id.* In some instances, the claimed methods involve defining a pattern by "selecting a plurality of areas on a display" and then "associate[ing] a level of abrasion with each of the plurality of areas." *See e.g.*, Memo Exhibit 3, '972 Patent, Claim 56.

42. Claim 2 of the '972 Patent is a dependent claim directed to a method including "a

plurality of said effective applied power levels are values which do not undesirably damage a material." Memo Exhibit 3, '972 Patent, Claim 2.

43. Claim 4 of the '972 Patent depends on Claim 2, adding that the material used for the claimed method is denim. Memo Exhibit 3, '972 Patent, Claim 4.

44. Claims 19, 43, 55, 82, 87, and 94 of the '972 Patent specify that that effective applied energy is "one of an energy density per unit time [EDPUT], power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser." Memo Exhibit 3, '972 Patent, Claims 19, 43, 55, 82, 87, 94.

45. The claim term "undesirably damage" does not appear in the specification of the '972 Patent. Memo Exhibit 3, '972 Patent.

46. The specification of the '972 Patent discusses damaging effects to materials that appear to be both intended and unintended. *Compare* Memo Exhibit 3, '972 Patent at Col. 3:43-44 (discussing "undesirably burning, punching through or otherwise harming the textile material") with Col. 7:3-5 ("higher EDPUTs may be associated with more aggressive abrasion patterns including fraying…").

47. The specification of the '972 Patent explains that "[t]he energy from the laser changes the look of the textile material without undesirably burning, punching through or otherwise harming the textile material. The basic operations of applying energy from a laser are described in U.S. Patent No. 5,990,444." Memo Exhibit 3, '972 Patent, Col. 3:41-46.

48. The specification of the '972 Patent explains:

> The EDPUT is of sufficient magnitude to fray the denim so that individual threads are exposed or actual holes are provided in the denim. This goes against the teaching in the above '444 patent, which teaches that punch through of the material is undesired. The specific 'fraying' effect, provides enough EPDUT to intentionally cause damage to the material, however in a controllable and desired fashion.

Memo Exhibit 3, ’972 Patent, Col. 12:15-23.

49. The specification of the ’972 Patent explains that the laser used in the invention had been used in the prior art for cutting operations, and “[t]he expectation is that these higher power lasers would unintentionally damage the material. However, by adjusting the EDPUT, higher power lasers can safely be used.” Memo Exhibit 3, ’972 Patent, Col. 13:1-13:4.

50. The specification of the ‘972 Patent describes worn looks that can be produced using the patented method, including “abrasion effects which simulate the look of a worn garment, whisker effects, frayed effects, as well as any other effect which is produced on a garment or other product made from a textile material and which makes the textile material look more like a used textile material.” Memo Exhibit 3, ‘972 Patent, Col. 3:30-35. According to the specification, this is accomplished because “[t]he applied energy from the laser changes the look of the textile material without undesirably burning, punching through, or otherwise harming the textile material.” *Id.*, Col. 3:40-44.

51. The specification of the ‘972 Patent states that EDPUT control is “infinite and can vary a few percent to several thousand percent along each scanned line from one scanned line to another.” Memo Exhibit 3, ’972 Patent, Col. 7:13-16.

52. The specification of the ’972 Patent equates “effective applied energy” with EDPUT, scan line speed, power level, speed level, duty cycle level, and distance. Memo Exhibit 3, ‘972 Patent, Col. 3:47-50, 3:57-60, 4:8-12, 4:17-21, 4:24-5:14.

53. The specification of the ’972 Patent defines “effective applied energy” as “effective applied power being applied in multiple sessions or times.” Memo Exhibit 3, Col. 3:62-64.

54. The term “damage” does not have a single meaning to one of ordinary skill in the

art. Memo Exhibit 7, Cole Report, ¶¶ 55, 126; Memo Exhibit 8, Pfefferkorn Report, ¶¶ 79-85.

Dated: September 1, 2015

Respectfully Submitted:

/s/ Staci Jennifer Riordan
Staci Jennifer Riordan
Neal J. Gauger
NIXON PEABODY LLP
Gas Company Tower
555 W. Fifth Street, 46th Floor
Los Angeles, CA 90013-1010
Telephone: 213-629-6000
Facsimile: 213-629-6001

Shawn G. Hansen
Jennifer Hayes
NIXON PEABODY LLP
2 Palo Alto Square, Suite 500
3000 El Camino Real
Palo Alto, CA 94306-2106
Telephone: 650-320-7700
Facsimile: 650-320-7701

Maia H. Harris
Michelle A. Flores
Charles Dell'Anno
NIXON PEABODY LLP
100 Summer Street
Boston, MA 02110-2131
Telephone: 617-345-1000
Facsimile: 617-345-1300

Counsel for Respondents
H & M Hennes & Mauritz L.P. and
H & M Hennes & Mauritz AB

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing document was served to the parties, in the manner indicated below, on September 1, 2015.

The Honorable Lisa R. Barton Secretary to the Commission U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 112 Washington, DC 20436	☒ **VIA ELECTRONIC FILING**
The Honorable MaryJoan McNamara Administrative Law Judge U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 317 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (to sarah.zimmerman@usitc.gov) ☒ **VIA U.S. MAIL**
Peter Sawert, Esq. Commission Investigative Attorney Office of Unfair Import Investigations U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 401 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (peter.sawert@usitc.gov)
COUNSEL FOR COMPLAINANTS REVOLAZE, LLC AND TECHNOLINES, LLC	
Cindy S. Ahn SCHIFF HARDIN LLP 233 S. Wacker Drive Suite 6600 Chicago, IL 60606 Benoit Quarmby MOLOLAMKEN LLP 540 Madison Avenue New York, NY 10022 Elizabeth Koehn Global IP Law Group, LLC 233 South Wacker Drive, 92nd Floor Chicago, IL 20004	☒ **VIA ELECTRONIC MAIL** (Revolaze@mololamken.com) (Revolaze@giplg.com)
COUNSEL FOR RESPONDENT THE GAP, INC.	
Marcia H. Sundeen GOODWIN PROCTER LLP 901 New York Ave, NW Washington, DC 20001 Aimee Soucie KENYON & KENYON LLP 1500 K Street, N.W. Washington, DC 20005-1257	☒ **VIA ELECTRONIC MAIL** (Msundeen@goodwinprocter.com) (DG-Goodwin_930@goodwinprocter.com) ☒ **VIA ELECTRONIC MAIL** (GapITC@kenyon.com)

COUNSEL FOR RESPONDENT KOOS MANUFACTURING, INC.	
Brian K. Brookey TUCKER ELLIS LLP 515 South Flower Street, Forty Second Floor Los Angeles, CA 90071-2223	☒ **VIA ELECTRONIC MAIL** (KoosITC@tuckerellis.com)
COUNSEL FOR EROGLU GIYIM SANAYI TICARET A.S.	
Janine A. Carlan ARENT FOX LLP 1717 K Street, N.W. Washington, DC 20006-5344	☒ **VIA ELECTRONIC MAIL** (ITC-930-Eroglu@arentfox.com)

/s/ Maia H. Harris
NIXON PEABODY LLP

UNITED STATES INTERNATIONAL TRADE COMMISSION
WASHINGTON, DC

Honorable MaryJoan McNamara, Administrative Law Judge

In the Matter of CERTAIN LASER ABRADED DENIM GARMENTS	Investigation No. 337-TA-930

H & M HENNES & MAURITZ L.P. AND H & M HENNES & MAURITZ AB'S APPENDIX OF EXHIBITS FILED IN SUPPORT OF ITS MOTION FOR SUMMARY DETERMINATION OF INVALIDITY OF THE ASSERTED PATENTS ON THE BASIS OF INDEFINITENESS

Pursuant to Rule 210.18 and Ground Rule 3.1, Respondents H & M Hennes & Mauritz L.P. and H & M Hennes & Mauritz AB (collectively, "H&M"), by and through undersigned counsel, submit the following Appendix of Exhibits filed in support of its Motion for Summary Determination of Invalidity of the Asserted Patents on the Basis of Indefiniteness, filed contemporaneously herewith ("Motion"). The following Exhibits are attached to the Memorandum and Points of Authorities in Support of H&M's Motion, also filed contemporaneously herewith ("Memo").

Memo Exhibit 1: United States Patent No. 6,140,602 to Costin dated October 31, 2000.

Memo Exhibit 2: United States Patent No. 6,664,505 to Martin dated December 16, 2003.

Memo Exhibit 3: United States Patent No. 6,819,972 to Martin et al. dated November 16, 2004.

Memo Exhibit 4: United States Patent Nos. 4,861,620 (Azuma); 4,847,184 (Taniguchi); 4,901,089 (Bricot); and 5,017,423 (Bossman et al.).

Memo Exhibit 5: United States Patent No. 5,567,207 (Lockman et al.).

Memo Exhibit 6: SU Patent No. 1,559,794 (Grigoryan et al.).

Memo Exhibit 7: Opening Expert Report of Christine W. (Jarvis) Cole, Ph. D. on Claim Construction Issues dated December 19, 2014 (CONTAINS CBI).

Memo Exhibit 8: Rebuttal Expert Report of Frank Pfefferkorn, Ph. D. Regarding Claim Construction Issues dated January 16, 2015.

Dated: September 1, 2015

Respectfully Submitted:

/s/ Staci Jennifer Riordan

Staci Jennifer Riordan
Neal J. Gauger
NIXON PEABODY LLP
Gas Company Tower
555 W. Fifth Street, 46th Floor
Los Angeles, CA 90013-1010
Telephone: 213-629-6000
Facsimile: 213-629-6001

Shawn G. Hansen
Jennifer Hayes
NIXON PEABODY LLP
2 Palo Alto Square, Suite 500
3000 El Camino Real
Palo Alto, CA 94306-2106
Telephone: 650-320-7700
Facsimile: 650-320-7701

Maia H. Harris
Michelle A. Flores
Charles Dell'Anno
NIXON PEABODY LLP
100 Summer Street
Boston, MA 02110-2131
Telephone: 617-345-1000
Facsimile: 617-345-1300

Counsel for Respondents
H & M Hennes & Mauritz L.P. and
H & M Hennes & Mauritz AB

CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing document was served to the parties, in the manner indicated below, on September 1, 2015.

The Honorable Lisa R. Barton Secretary to the Commission U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 112 Washington, DC 20436	☒ **VIA ELECTRONIC FILING**
The Honorable MaryJoan McNamara Administrative Law Judge U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 317 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (to sarah.zimmerman@usitc.gov) ☒ **VIA U.S. MAIL**
Peter Sawert, Esq. Commission Investigative Attorney Office of Unfair Import Investigations U.S. INTERNATIONAL TRADE COMMISSION 500 E Street, S.W., Room 401 Washington, DC 20436	☒ **VIA ELECTRONIC MAIL** (peter.sawert@usitc.gov)
COUNSEL FOR COMPLAINANTS REVOLAZE, LLC AND TECHNOLINES, LLC	
Cindy S. Ahn SCHIFF HARDIN LLP 233 S. Wacker Drive Suite 6600 Chicago, IL 60606 Benoit Quarmby MOLOLAMKEN LLP 540 Madison Avenue New York, NY 10022 Elizabeth Koehn Global IP Law Group, LLC 233 South Wacker Drive, 92nd Floor Chicago, IL 20004	☒ **VIA ELECTRONIC MAIL** (Revolaze@mololamken.com) (Revolaze@giplg.com)
COUNSEL FOR RESPONDENT THE GAP, INC.	
Marcia H. Sundeen GOODWIN PROCTER LLP 901 New York Ave, NW Washington, DC 20001	☒ **VIA ELECTRONIC MAIL** (Msundeen@goodwinprocter.com) (DG-Goodwin_930@goodwinprocter.com)
Aimee Soucie KENYON & KENYON LLP 1500 K Street, N.W. Washington, DC 20005-1257	☒ **VIA ELECTRONIC MAIL** (GapITC@kenyon.com)

COUNSEL FOR RESPONDENT KOOS MANUFACTURING, INC.	
Brian K. Brookey TUCKER ELLIS LLP 515 South Flower Street, Forty Second Floor Los Angeles, CA 90071-2223	☒ **VIA ELECTRONIC MAIL** (KoosITC@tuckerellis.com)
COUNSEL FOR EROGLU GIYIM SANAYI TICARET A.S.	
Janine A. Carlan ARENT FOX LLP 1717 K Street, N.W. Washington, DC 20006-5344	☒ **VIA ELECTRONIC MAIL** (ITC-930-Eroglu@arentfox.com)

/s/ Maia H. Harris
NIXON PEABODY LLP

EXHIBIT 1

US006140602A

United States Patent [19]

Costin

[11] Patent Number: 6,140,602

[45] Date of Patent: Oct. 31, 2000

[54] MARKING OF FABRICS AND OTHER MATERIALS USING A LASER

[75] Inventor: Darryl Costin, Perrysburg, Ohio

[73] Assignee: Technolines LLC, Perrysburg, Ohio

[21] Appl. No.: 08/844,114

[22] Filed: Apr. 29, 1997

[51] Int. Cl.[7] B23K 26/40

[52] U.S. Cl. 219/121.69; 219/121.68

[58] Field of Search 219/121.6, 121.61, 219/121.62, 121.68, 121.69, 121.8, 121.83, 121.85, 121.67, 121.75; 8/444

[56] References Cited

U.S. PATENT DOCUMENTS

4,307,282	12/1981	Gappa	219/121.8
4,316,073	2/1982	Lemelson	219/121.8
4,378,480	3/1983	Langhans	219/121.77
4,629,858	12/1986	Kyle	219/121.69
5,200,592	4/1993	Yabu	219/121.67
5,262,613	11/1993	Norris et al.	219/121.68
5,367,141	11/1994	Piltch	219/121.67
5,567,207	10/1996	Lockman et al.	8/444
5,605,641	2/1997	Chiba et al.	219/121.69

FOREIGN PATENT DOCUMENTS

2698302	5/1994	France .	
3029104	2/1982	Germany	219/121.8
3916126	11/1990	Germany .	
61-242783	10/1986	Japan	219/121.8
62-94343	4/1987	Japan	219/121.69
62-110892	5/1987	Japan	219/121.77
62-259691	11/1987	Japan	219/121.75
63-273588	11/1988	Japan	219/121.75
1-95885	4/1989	Japan	219/121.69
2294656	5/1996	United Kingdom .	
2 294656	8/1996	United Kingdom .	

OTHER PUBLICATIONS

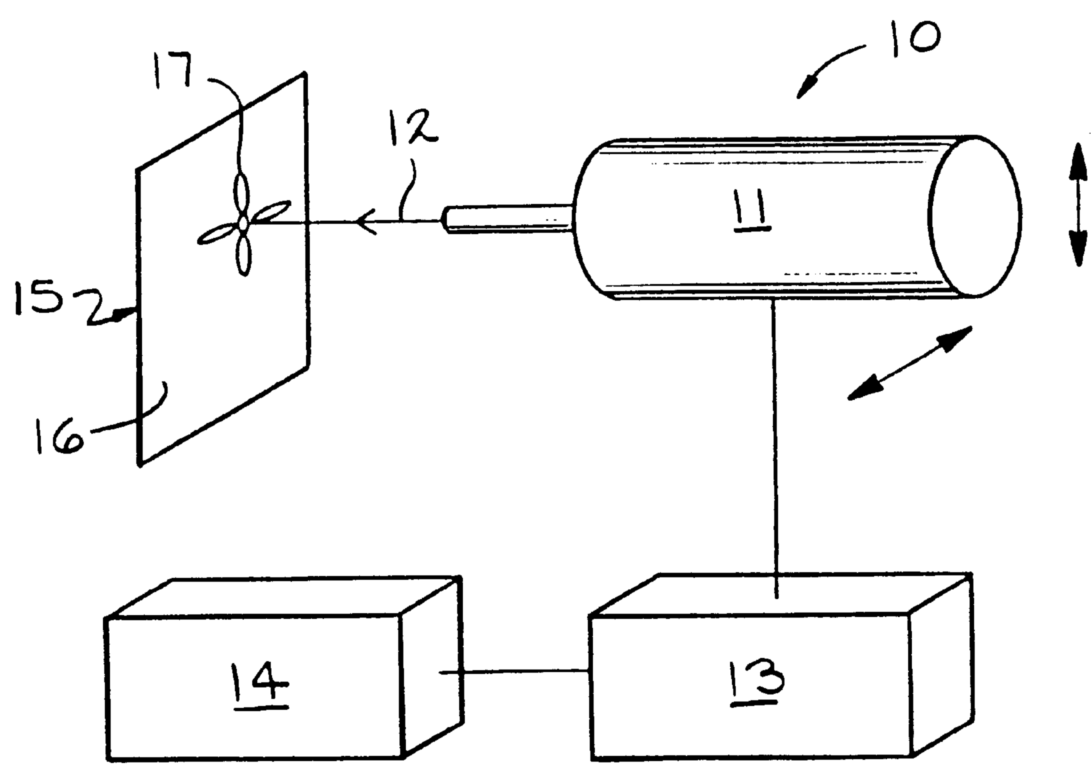
Stevenson, Richard L., Industrial Strength Laser Marking, 1992, Florida.

Primary Examiner—Geoffrey S. Evans
Attorney, Agent, or Firm—Scott C. Harris, Esq.

[57] ABSTRACT

A unique method imparts laser induced patterns and other designs on thin fabrics and leathers. The method uses a laser beam to slightly penetrate the surface of the product at a controlled specific speed. The laser beam is directed at the product either directly or through mirrors, shutters or lenses. The speed of the laser beam relative to the surface of the product is controlled within a predetermined range. Specific identification and control of this relative speed for a particular product are the keys to overcoming technical barriers which have prevented such use of lasers in the past. Preferably a computer is used to provide a signal to a drive mechanism to control the relative speed. The drive mechanism can control movement of the laser, the product, a mirror or a lens.

154 Claims, 6 Drawing Sheets



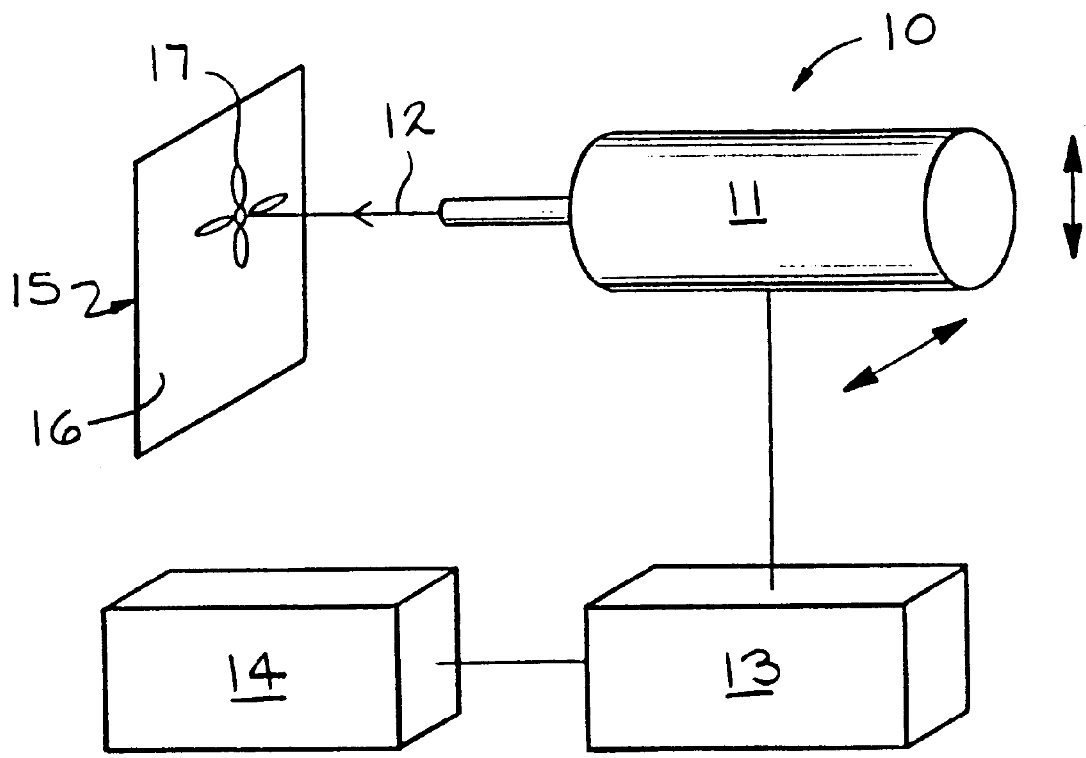


FIG. 1

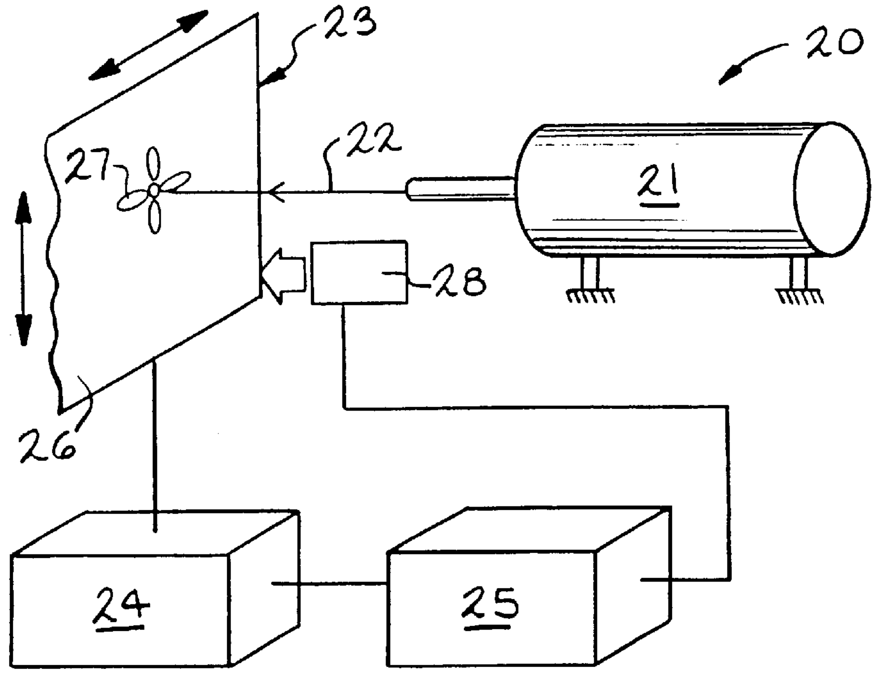


FIG 2

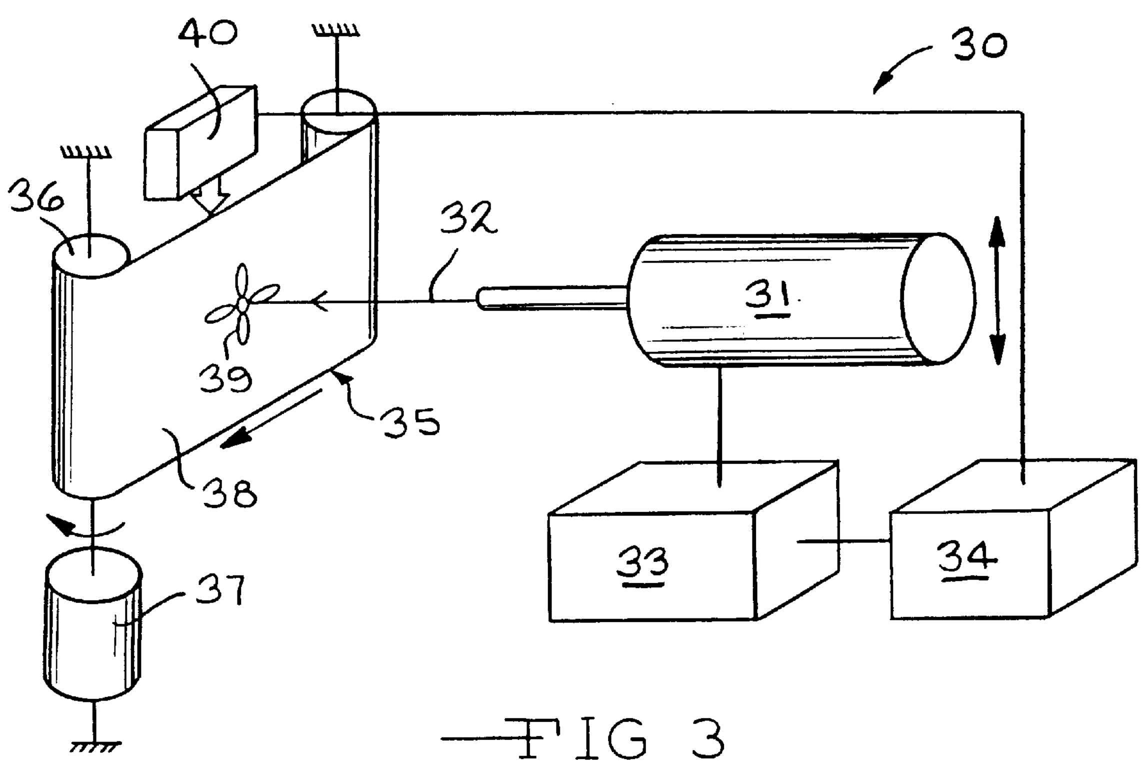


FIG 3

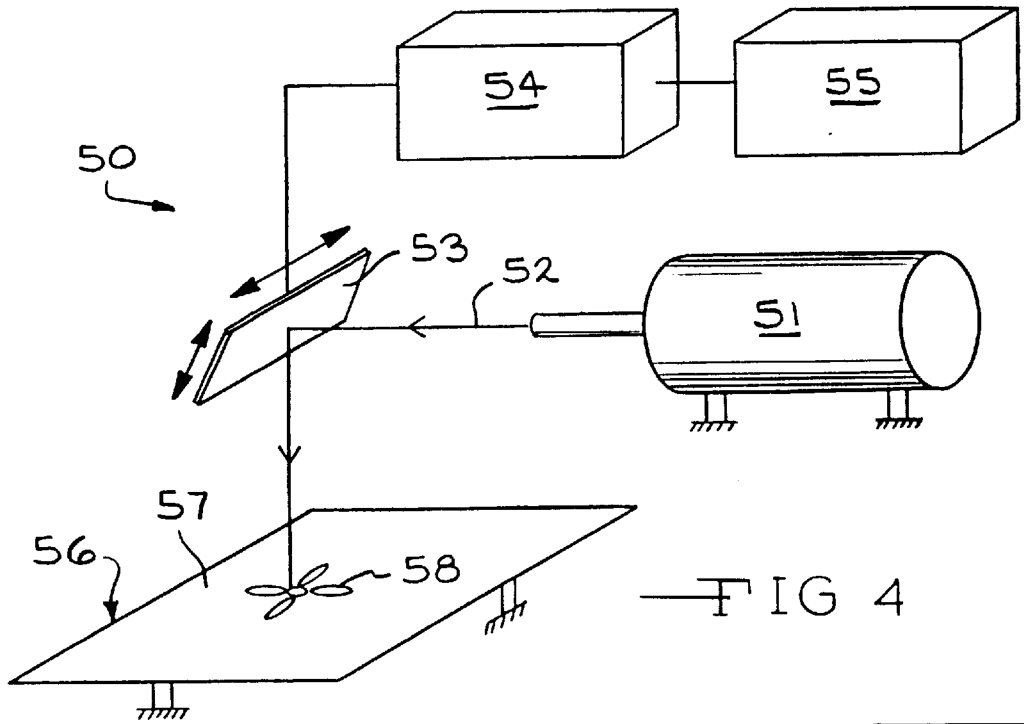


FIG 4

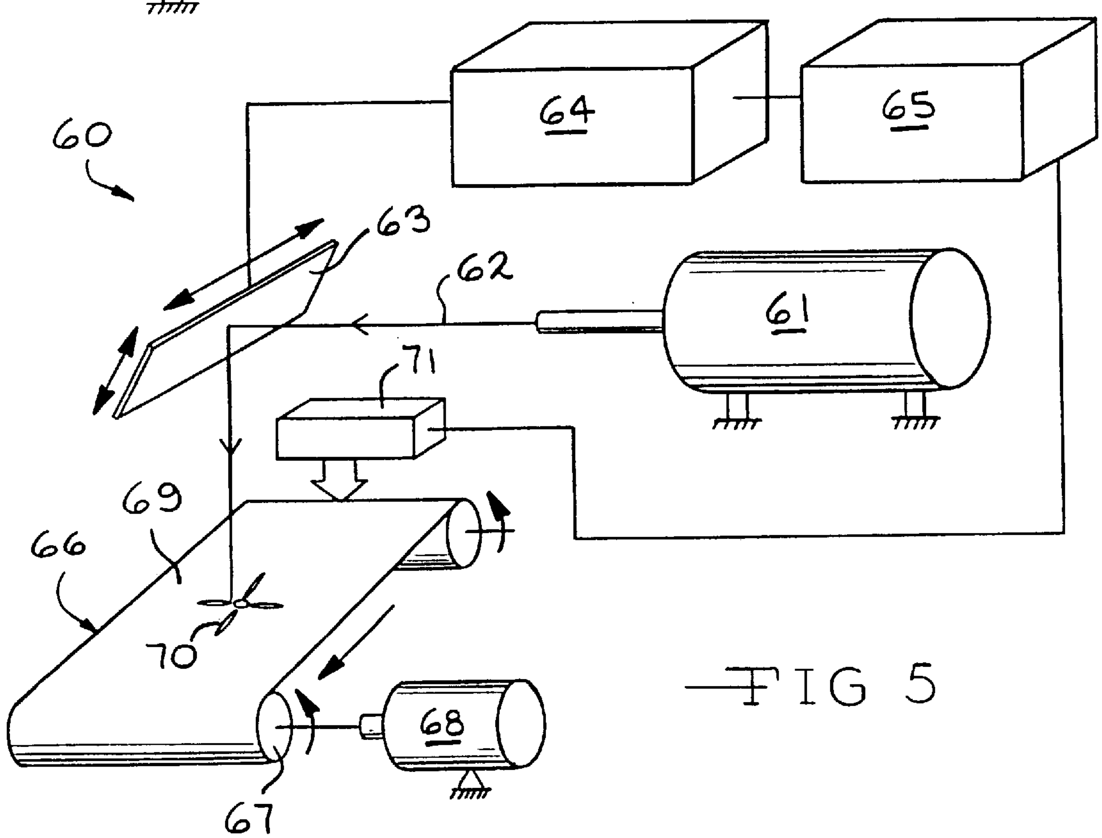


FIG 5

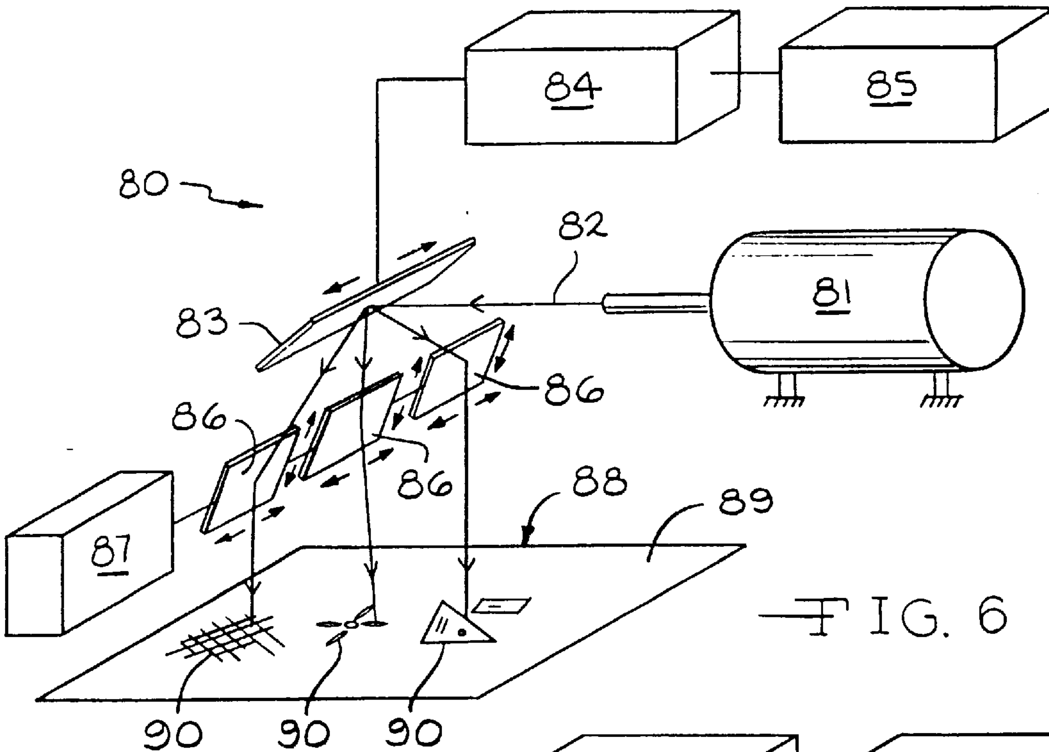

84
85
80
82
81
83
86
86
86
86
88
89
87
90
90
90

FIG. 6

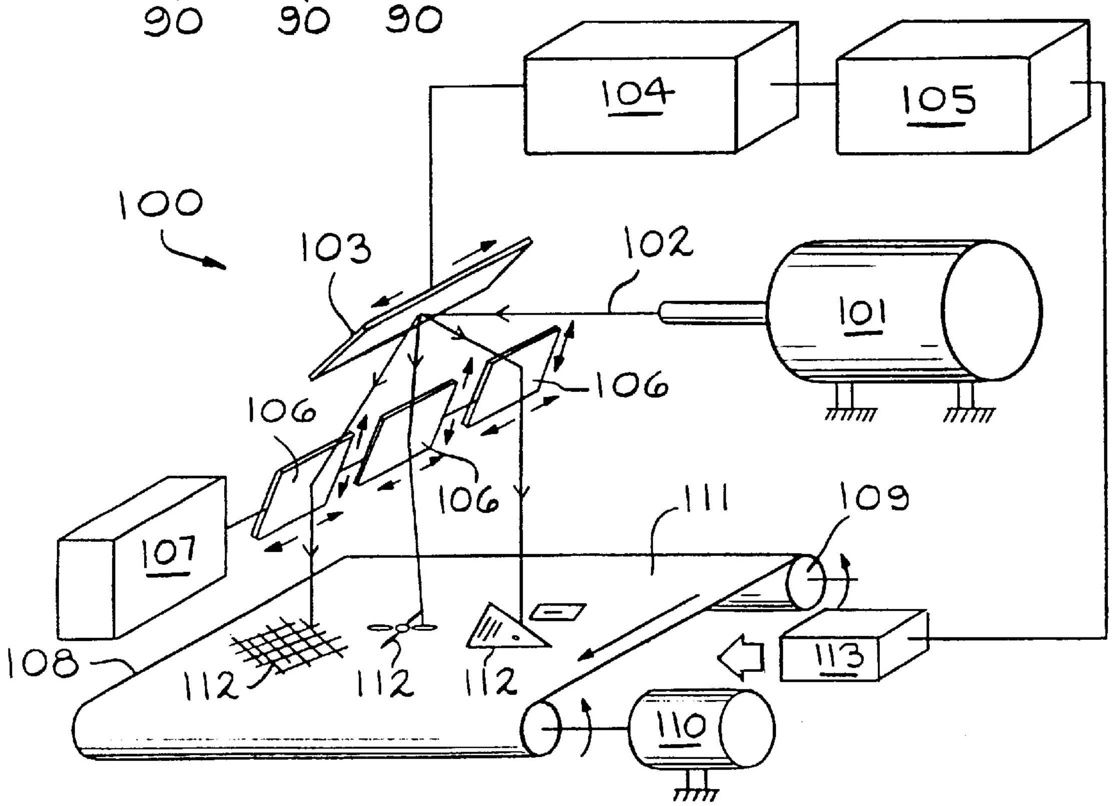

104
105
100
103
102
101
106
106
106
106
111
109
107
108
112
112
112
113
110

FIG. 7

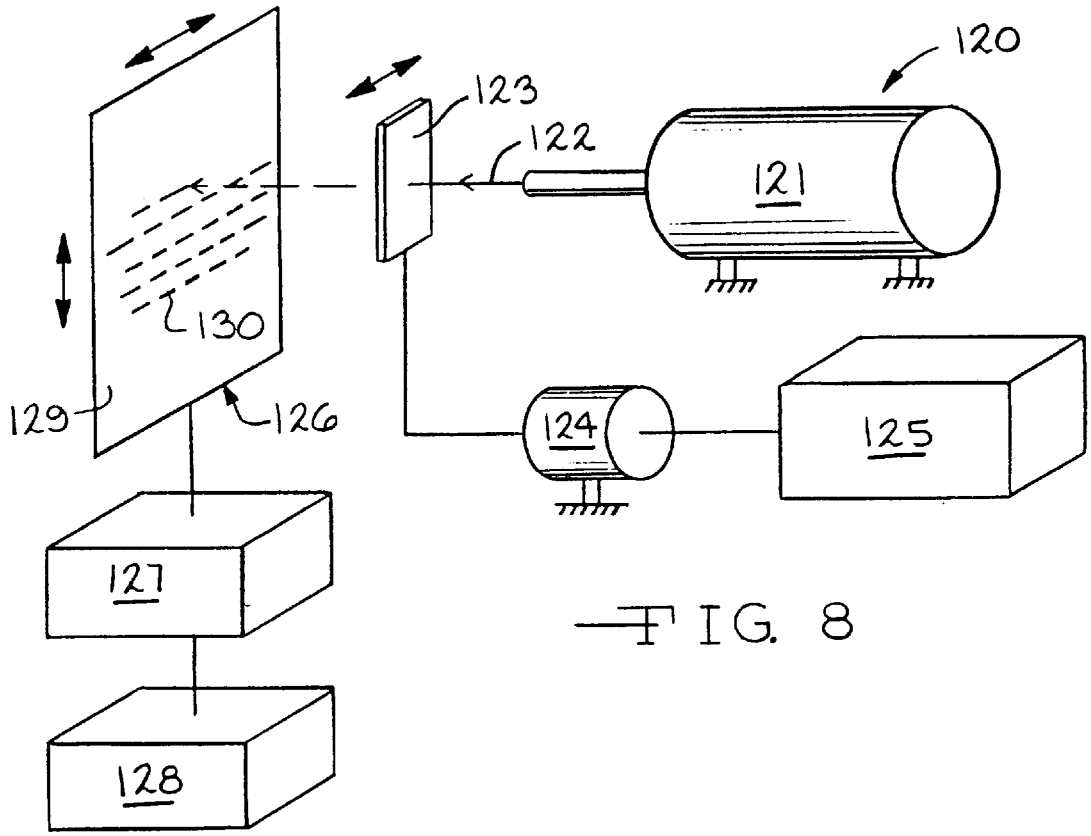
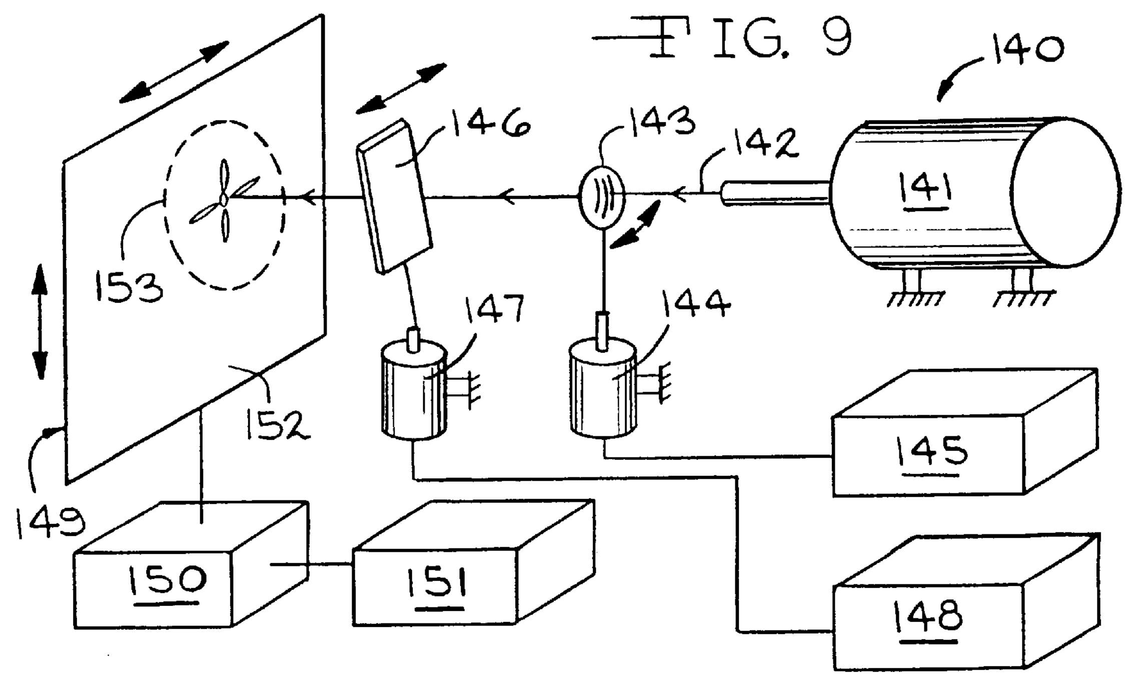

120
123
122
121
130
129
126
124
125
127
128

FIG. 8

FIG. 9


140
146
143
142
141
153
147
144
152
145
149
150
151
148

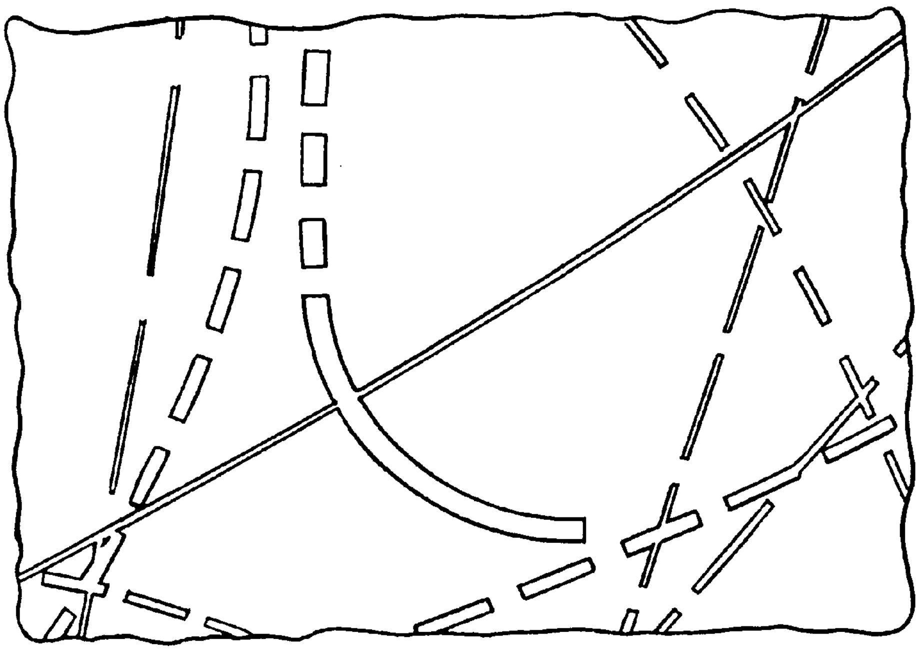


FIG. 10

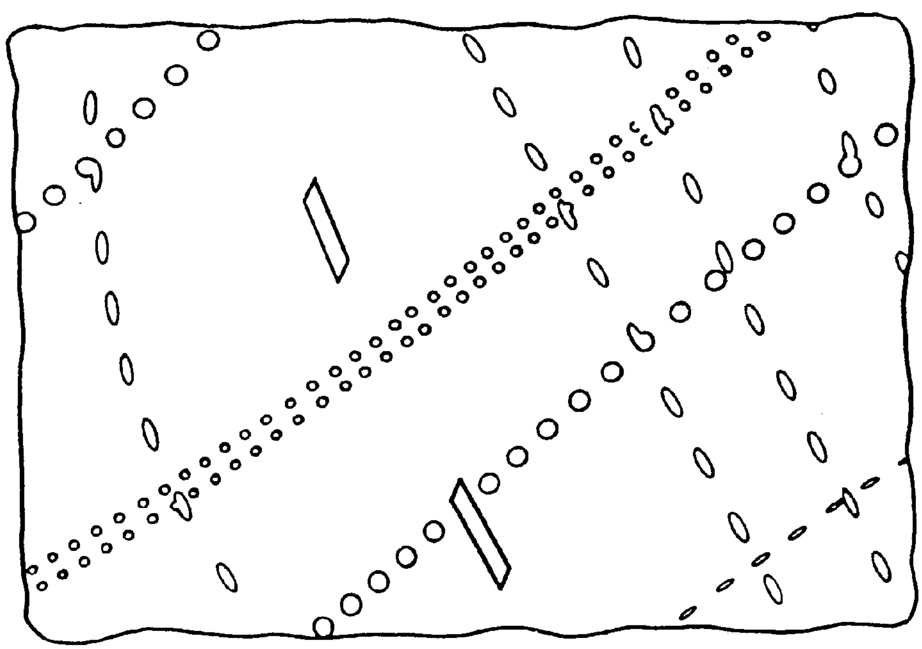


FIG 11

MARKING OF FABRICS AND OTHER MATERIALS USING A LASER

BACKGROUND OF THE INVENTION

This invention relates in general to a method of forming designs on fabrics and leathers. In particular, this invention relates to a specific method of forming laser induced patterns and other designs on thin fabrics and leathers.

Thin fabrics and leathers have commonly been used to make clothing, footwear, purses and wallets, vehicle interiors, furniture coverings, wall coverings and many other manufactured goods. Patterns and other designs have been formed on the thin fabrics and leathers to give them a more attractive appearance.

The typical methods of forming designs on thin fabrics are chemical dyeing, weaving, ink jet printing and embossing. Unfortunately, such methods are either very costly in terms of capital investment and operating cost or they are plagued with environmental problems.

Intricate designs on thin fabrics and leathers are often more interesting and attractive than simple designs. However, there has previously been no cost-effective method of forming intricate designs on leathers. Methods such as chemical dyeing and weaving which can form intricate designs on fabrics are not suitable for forming such designs on leathers. As a result, intricate designs have only been formed on leathers by handworking methods or other costly methods.

Lasers have been used in the fabric industry to cut thin fabrics into separate pieces. They have also been used to engrave designs on carpets and heavy pile fabrics. In the past, certain technical barriers have prevented the use of lasers to form designs on thin fabrics and leathers. When such use was attempted, the laser beam caused carbonization, complete melting and/or burn-through at the point of contact. This resulted in complete penetration and the formation of an undesirable hole or defect in the fabric or leather. Particular difficulties were encountered with thin fabrics having an irregular thickness.

If the technical barriers could be overcome, a laser would be a desirable method of forming designs on thin fabrics and leathers. For one thing, a laser is well adapted for forming intricate designs on products. Moreover, laser manufacturing methods are generally cost-effective and do not cause environmental problems. Thus it would be desirable to provide a suitable method of using a laser to form designs on thin fabrics and leathers.

SUMMARY OF THE INVENTION

This invention relates to a unique method to impart laser induced patterns and other designs on thin fabrics and leathers. The method uses a laser beam to slightly penetrate the surface of the product at a controlled specific speed. The laser beam is directed at the product either directly or through mirrors, shutters or lenses. The speed of the laser beam relative to the surface of the product is controlled within a predetermined range. Specific identification and control of this relative speed for a particular product are the keys to overcoming technical barriers which have prevented such use of lasers in the past. Preferably a computer is used to provide a signal to a drive mechanism to control the relative speed. The drive mechanism can control movement of the laser, the product, a mirror or a lens.

This invention provides many benefits unavailable in the prior art. Laser induced designs can be imparted onto thin

fabrics and leathers, overcoming the technical barriers of carbonization, complete melting and/or burn-through. New effects and designs can be imparted onto thin fabrics and leathers which are not possible by any other means, thereby creating new products with expanded market opportunities. Intricate laser induced designs can be imparted onto leather and suede where unique designs are seldom found. The products made by this method have superior mechanical properties and chemical stability compared to chemical dyed products.

The designed fabrics and leathers can be produced very cost efficiently with modern automatic laser systems. The operating parameters for the particular kind of fabric or leather are created, modulated and controlled by computer. The method avoids the costs associated with a heavy investment in capital equipment and environmental protection equipment. No preprocessing of the fabric such as soaking or spraying is required prior to the impingement of the laser beam. No postprocessing of the fabric is required following the impingement of the laser beam.

Various objects and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiment, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** through **9** are schematic views of a laser method of forming designs on thin fabrics and leathers in accordance with this invention.

FIG. **1** illustrates a method in which the laser is moved to control the speed of the laser beam relative to the surface of the fabric.

FIG. **2** illustrates a method in which the fabric is moved to control the speed of the laser beam relative to the surface of the fabric.

FIG. **3** illustrates a method in which both the laser and the fabric are moved, and specifically where the fabric is positioned on a moving roll.

FIG. **4** illustrates a method in which a mirror is moved to direct the laser beam onto the surface of the fabric.

FIG. **5** illustrates a method in which a mirror is moved to direct the laser beam onto the surface of the fabric, and where the fabric is positioned on a moving roll.

FIG. **6** illustrates a method in which a main mirror and a plurality of secondary mirrors are moved to direct the laser beam onto the surface of the fabric.

FIG. **7** illustrates a method in which a main mirror and a plurality of secondary mirrors are moved to direct the laser beam onto the surface of the fabric, and where the fabric is positioned on a moving roll.

FIG. **8** illustrates a method in which a shutter periodically interrupts the laser beam to form a discontinuous design on the surface of the fabric.

FIG. **9** illustrates a method in which a lens is moved to direct the laser beam onto the surface of the fabric, and in which a shutter periodically interrupts the laser beam to form a discontinuous design on the surface of the fabric.

FIG. **10** illustrates a laser design formed on denim fabric in accordance with this invention.

FIG. **11** illustrates a laser design formed on leather in accordance with this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, there is illustrated in FIG. **1** a laser method of forming designs on thin fabrics and

leathers in accordance with this invention. The method utilizes the apparatus indicated generally at **10**. The apparatus **10** includes a laser **11** which generates a laser beam **12**. The laser **11** is positioned so that it can be moved in the vertical and horizontal directions indicated by the arrows in the drawing. Such movement results in a corresponding movement of the laser beam **12**. A drive mechanism in the form of a laser drive **13** is connected to the laser **11**. The laser drive **13** is adapted to cause movement of the laser **11** in the vertical and horizontal directions. Alternatively, the laser drive **13** could cause the laser **11** to rotate vertically and horizontally on a stationary pivot.

An electronic controller such as a computer **14** is connected to the laser drive **13**. The computer **14** is adapted to provide a signal to the laser drive **13** to control movement of the laser **11**. The computer **14** is programmed by particular software (not shown) developed to control such movement.

The laser **11** is positioned to generate a laser beam **12** in the direction of a thin fabric **15**. The fabric **15** includes a surface **16**. In operation, the laser **11** is activated and generates the laser beam **12**. The laser beam **12** contacts the surface **16** of the fabric **15**. The computer **14** provides signals to the laser drive **13**. In response to the signals, the laser drive **13** causes movement of the laser **11** and the laser beam **12**. Movement of the laser beam **12** in contact with the surface **16** of the fabric **15** causes a design **17** to be formed on the surface **16**.

The laser beam **12** moves at a particular speed relative to the surface **16** of the fabric **15**. In accordance with the method of this invention, the speed of the laser beam **12** relative to the surface **16** of the fabric **15** is controlled within a predetermined range. It has now been discovered that specific identification and control of this speed are the keys to preventing carbonization, complete melting and/or burn-through of the fabric. This invention thereby overcomes the technical barriers which have prevented the use of lasers in the past to form designs on thin fabrics and leathers.

It is necessary to maintain this speed at a level above a Threshold Speed where the laser beam fully penetrates the fabric and results in carbonization, complete melting and/or burn-through. However, it is also necessary to maintain this speed at a level below a Maximum Speed where a design cannot be formed on the fabric. The range of speeds between the Threshold Speed and the Maximum Speed will be referred to herein as the Process Operating Speed. The Process Operating Speed is a function of the type of fabric or leather material, the thickness of the material, the construction of the material, the power and wavelength of the laser beam, the distance between the laser and the material, and the type of design formed on the surface of the material. Statistically designed experiments can best be employed to determine the specific Process Operating Speed for each material and method. Further, statistical models can be used to determine the Process Operating Speed for new fabrics or leathers and new lasers. The Process Operating Speed for a variety of thin fabrics and leathers is shown in Table I, along with the type of laser designs that can be formed on the materials. The variation in Process Operating Speed is due to the factors mentioned above.

TABLE I

Process Operating Speed for Laser Design on General Fabrics and Leathers

Material (Woven, Nonwoven or Knitted)	Design	Operating Speed (m/sec)
Cotton	SC	0.08–1.5
Rayon	SC	0.08–1.5
Acetate	SC	0.08–1.5
Nylon	SC, FP	1.0–1.5
Artificial Fiber	SC, FP	0.08–1.5
Half Wool	SC, R	1.0–1.5
Wool	SC, R	0.01–1.0
Flax	SC, R	0.05–1.5
Natural Silk	SC	1.0–1.5
Artificial Silk	SC, FP	1.0–1.5
Mixed Fiber Fabric	SC, FP, R	0.01–1.5
Chemical Fiber Fabric	SC, FP, R	0.01–1.0
Polyamide, Polyamide Chloride	SC, FP	0.01–1.0
Lavsan	SC	0.01–1.0
Pig Leather	SC, FP, R	0.01–1.0
Kid Leather	SC, FP, R	0.01–1.0
Box Calf Leather	SC, FP, R	0.01–1.0
Chamois Leather	SC, FP, R	0.01–1.0
Artificial Leather	SC, FP, R	0.01–1.0

Design Key:
SC = Single Color,
FP = Full Penetrating,
R = Relief

It has also been discovered that there is a Critical Operating Speed above which the propensity to not form a design on the fabric increases, and below which the propensity to cause burn-through, complete melting and/or carbonization increases. Statistically designed experiments can be used to determine the Critical Operating Speed for a particular material and method. Since the Critical Operating Speed of new fabrics and leathers is a function of numerous material and process variables, statistical quantitative models derived from computer designed experiments have been employed to determine the speed.

In the embodiment illustrated in FIG. **1**, the computer program feeds the laser drive **13** with the specific movements and timing necessary to form the desired design **17** on the fabric **15** and maintain the Critical Operating Speed. The Critical Operating Speed for a variety of thin fabrics and leathers is shown in Table II. It can be seen that the Critical Operating Speed varied between a low of 0.01 meters/second for chamois leather suede and a high of 1.2 meters/second for rayon silk. The Critical Operating Speed for all other thin fabrics and leathers varied between these two extremes.

TABLE II

Critical Operating Speed for Laser Design on Specific Fabrics and Leathers

Material	Design	Critical Operating Speed +/− 0.02 (m/sec)
Artificial Leather	SC, R	0.05
Rayon Silk (100%)	SC	1.2
Nylon Silk (100%)	FP	1.2
Cotton Velveteen (100%)	SC, R	0.8
Heavy Half Wool (62% Wool, 23% Rayon, 15% Nylon)	SC, R	0.6
Heavy Wool	SC, R	0.4
Nonwoven Canvas (70% Cotton, 30% Rayon)	SC	0.9
Raincoat Fabric (100% Cotton)	SC	1.2

TABLE II-continued

Critical Operating Speed for Laser Design on Specific Fabrics and Leathers

Material	Design	Critical Operating Speed +/− 0.02 (m/sec)
Shirt & Chemise Fabric (100% Cotton)	SC	1.2
Clothing Fabric (50% Cotton, 50% Polyamide)	SC, FP	1.0
Denim Fabric (100% Cotton)	SC	1.0
Chamois Leather Suede	SC, R	0.01
Pig Leather	SC, R	0.05

Design Key:
SC = Single Color,
FP = Full Penetrating,
R = Relief

The specific laser used can be any conventional laser capable of functioning as described above. A preferred laser is a CO_2 laser with a radiation capacity of about 5–150 watts and a wavelength of about 10.6 micrometers, with a distance between the laser and the fabric of about 0.08–0.5 meters. Other lasers such as a well-known YAG laser having a wavelength of about 1.06 micrometers can also be used in this invention.

The laser beam can be modulated or otherwise manipulated to produce different effects on the design. Suitable means include electro-optic modulators, acoustic optic modulators, laser-oscillated voltage, On and Off synchronous mechanical devices, masking methods, methods of applying mechanical shift, or systems in sync with laser scanning operations.

The electronic controller may be embodied as any conventional computer, microprocessor, or other similar electronic computing apparatus. Additionally, any suitable software or computing language may be used to control movement of the laser.

This invention provides for the production of unique laser designs on a variety of thin fabrics and a variety of leathers. The fabrics can be formed from natural or artificial fibers. The fabrics can be woven, nonwoven or knitted. Specific thin fabrics include cotton, rayon, nylon, wool, natural and artificial silk, acetate, flax, polyamide, lavsan, half wool, denim, raincoat fabric, woven and nonwoven canvas, and mixtures thereof. A preferred thin fabric is denim. Specific leathers include kid leather, lamb leather, pig leather, chamois leather, calf leather, suede and artificial leather.

A variety of different types of designs can be formed on thin fabrics and leathers in accordance with this invention by using a moving or stationary laser and a moving or stationary product. More complex designs can be formed by additionally employing mirrors, lenses, shutters, or combinations thereof. The design can be continuous or discontinuous, straight or curved, and simple or intricate. Thick or thin lines of design can be formed. The designs can be single or multiple color, full or partial penetrating, relief or flat, and combinations thereof. This invention allows for the creation of standard designs typically provided by more expensive means, as well as the creation of entirely new designs that are not possible to achieve by any other means thereby providing new products for expanded market opportunities. For example, the intricate laser designs imparted onto leathers are unique because alternate processes to impart such designs onto leather are rare and totally cost

inefficient. This invention can then be used to impart significant design patterns onto car leather interiors, jackets, boots, purses and wallets which are typically only differentiated by color. It is also possible to use this invention to create stencil laser patterns onto thin fabrics and leathers, for example to form monograms on the material.

The designs are formed by impingement of the laser beam on the surface of the thin fabric or leather. The laser beam destroys or changes a small portion of the material or dye. The ratio of the material destroyed or changed to the dye destroyed or changed is a function of the dye composition, quantity and level of fixation, and the material composition and construction such as type and interlacing of fiber. The laser beam can form a design on the material by destroying, melting, shrinking, rumpling, crumpling, creping, watering or crimping the material.

The designed thin fabrics and leathers in accordance with this invention can be used to make novel clothing, footwear, purses and wallets, vehicle interiors, furniture coverings and wall coverings. This invention can offer unique product designs to the fashion industry, footwear market, furniture business, home decorative market, automotive industry, and boat and airline industries.

A surprising benefit of this invention is that thin fabrics and leathers with designs produced by this invention have mechanical properties and chemical stability superior to those products produced by chemical dye processes. Table III illustrates this improvement in chemical stability of the laser designed thin fabrics and leathers. Samples of thin fabrics and leather were subjected to washing and rubbing treatments and then judged for the amount of color retained, uniformity of color, and depth of color. The scores in the table are a relative quality index with 5 being the best rating, essentially equivalent to untreated material. In all cases, the relative quality of the laser designed fabric was equal or superior to the chemical dyed fabric following high temperature soap washing, room temperature washing, and dry and wet friction testing.

TABLE III

Chemical Stability of Laser Design Fabrics and Leather vs. Chemical Design

Material	Design	SHTW	RTW	DFT	WFT
Rayon	Chemical	5	4–5	4	4
	Laser	5	4–5	4–5	5
Nylon	Chemical	5	4	4	4
	Laser	5	5	5	5
Nonwoven Canvas	Chemical	5	4	4	4
	Laser	5	5	5	5
Pig Leather	Chemical	5		4	3–4
	Laser	5		5	4–5

Design Key:
SHTW = Simulated High Temperature Soap Wash,
RTW = Room Temperature Wash,
DFT = Dry Friction Test,
WFT = Wet Friction Test

Table IV illustrates the significant improvement in mechanical properties of the laser designed fabrics versus the conventional designed fabrics. The significant improvement in tensile and elongation properties for the heavy wool laser design is particularly surprising and striking.

TABLE IV

Mechanical Properties of Laser Design Fabrics and Leather vs. Chemical Design

Material	Design	Load (Kg) Warp	Load (Kg) Woof	Elongation (%) Warp	Elongation (%) Woof
Rayon	Virgin	232.4	229.7	15.2	16.9
	Chemical	230.9	229.1	14.9	16.7
	Laser	231	229.5	14.9	16.8
Nylon	Virgin	256.8	252.4	19.8	20.2
	Chemical	251.4	250.3	19.2	20.0
	Laser	256.6	251.8	19.4	20.1
Nonwoven	Virgin	210.2	208.7	18.7	19.2
Canvas	Chemical	208.9	207.4	18.2	18.8
	Laser	209.1	207.8	18.5	18.8
Pig Leather	Virgin	1.4		35	
	Chemical	1.4		35	
	Laser	1.4		35	
Heavy Wool	Virgin	248.8	192.1	17.2	17.3
	Chemical	111.2	46.4	5.7	5.2
	Laser	247	190.1	17	17

Design Key:
Virgin = No Design,
Chemical = Chemical Design,
Laser = Laser Design.
Sample Size = 50 × 200 mm.

FIGS. **2** through **9** illustrate alternative embodiments of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. Referring now to FIG. **2**, there is illustrated a second embodiment which utilizes the apparatus indicated generally at **20**. The apparatus **20** includes a laser **21** which generates a laser beam **22**. Unlike the first embodiment illustrated in FIG. **1**, the laser **21** is not positioned so that it can be moved in the vertical and horizontal directions. Rather, the laser **21** is in a stationary position.

The laser **21** is positioned to generate a laser beam **22** in the direction of a thin fabric **23**. A drive mechanism in the form of a product drive **24** is connected to the fabric **23**. The product drive **24** is adapted to cause movement of the fabric **23** in the vertical and horizontal directions, as shown by the arrows in the drawing. An electronic controller such as a computer **25** is connected to the product drive **24**. The computer **25** is adapted to provide a signal to the product drive **24** to control movement of the fabric **23**. The computer **25** is programmed by particular software (not shown) developed to control such movement.

In operation, the laser **21** is activated and generates the laser beam **22** in the direction of the fabric **23**. The fabric **23** includes a surface **26**. The laser beam **22** contacts the surface **26** of the fabric **23**. The computer **25** provides signals to the product drive **24**. In response to the signals, the product drive **24** causes movement of the surface **26** of the fabric **23**. Movement of the surface **26** of the fabric **23** in contact with the laser beam **22** causes a design **27** to be formed on the surface **26**. As described above, the speed of the laser beam **22** relative to the surface **26** of the fabric **23** is controlled within a predetermined range. In this embodiment, the computer **25** provides signals to the product drive **24** to control the specific movements and timing of the fabric **23** to form the specific desired design **27** and to maintain the Critical Operating Speed.

To prevent carbonization, complete melting, and/or burn-through of a fabric **23** in which the thickness varies nonuniformly, a sensor **28** can continuously detect the thickness of the fabric **23** prior to contact with the laser beam **22**. The sensor **28** provides a signal to the computer **25**, and the computer **25** in turn provides a signal to the product drive **24** to adjust the relative speed in view of the detected thickness. Such thickness sensors are common in the paper making industry.

Referring now to FIG. **3**, there is illustrated a third embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. This third embodiment is a continuous method, and as a result is more economical than the first and second embodiments. The method utilizes the apparatus indicated generally at **30**. The apparatus **30** includes a laser **31** which generates a laser beam **32**. The laser **31** is positioned so that it can be moved in the vertical direction indicated by the arrow in the drawing. Such movement results in a corresponding movement of the laser beam **32**. A drive mechanism in the form of a laser drive **33** is connected to the laser **31**. The laser drive **33** is adapted to cause movement of the laser **31** in the vertical direction.

An electronic controller such as a computer **34** is connected to the laser drive **33**. The computer **34** is adapted to provide a signal to the laser drive **33** to control movement of the laser **31**. The computer **34** is programmed by particular software (not shown) developed to control such movement.

The laser **31** is positioned to generate a laser beam **32** in the direction of a thin fabric **35**. The fabric **35** is positioned on a moving roll **36**. A drive mechanism in the form of a product drive **37** is connected to the moving roll **36**. The product drive **37** is adapted to cause rotation of the moving roll **36** and thus continuous movement of the fabric **35** in the horizontal direction, as shown by the arrows in the drawing.

In operation, the laser **31** is activated and generates the laser beam **32** in the direction of the fabric **35**. The fabric **35** includes a surface **38**. The laser beam **32** contacts the surface **38** of the fabric **35**. The computer **34** provides signals to the laser drive **33**. In response to the signals, the laser drive **33** causes movement of laser **31** and the laser beam **32**. Movement of the laser beam **32** in contact with the moving surface **38** of the fabric **35** causes a design **39** to be formed on the surface **38**. As described above, the speed of the laser beam **32** relative to the surface **38** of the fabric **35** is controlled within a predetermined range. In this embodiment, the specific movements and timing of the laser **31** and the fabric roll **36** are coordinated to form the specific desired design **39** and to maintain the Critical Operating Speed. A sensor **40** can continuously detect the thickness of the fabric **35** prior to contact with the laser beam **32** and provide a signal to the computer **34** to adjust the relative speed.

Referring now to FIG. **4**, there is illustrated a fourth embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. Like the third embodiment, this fourth embodiment is a more economical method than the first and second embodiments. The method utilizes the apparatus indicated generally at **50**. The apparatus **50** includes a laser **51** which generates a laser beam **52**. The laser **51** is in a stationary position.

The laser **51** is positioned to generate a laser beam **52** in the direction of a mirror **53**. In turn, the mirror **53** is positioned to deflect the laser beam **52** in the direction of a thin fabric **56**. A drive mechanism in the form of a mirror drive **54** is connected to the mirror **53**. The mirror drive **54** is adapted to cause movement of the mirror **53** in the vertical and horizontal directions, as shown by the arrows in the drawing. An electronic controller such as a computer **55** is connected to the mirror drive **54**. The computer **55** is adapted to provide a signal to the mirror drive **54** to control movement of the mirror **53**. The computer **55** is programmed by particular software (not shown) developed to control such movement.

In operation, the laser **41** is activated and generates the laser beam **52** in the direction of the mirror **53**. The mirror **53** deflects the laser beam **52** in the direction of the fabric **56**. The fabric **56** includes a surface **57**. The laser beam **52** contacts the surface **57** of the fabric **56**. The computer **55** provides a signal to the mirror drive **54**. In response to the signal, the mirror drive **54** causes movement of the mirror **53** which causes movement of the laser beam **52**. Movement of the laser beam **52** in contact with the surface **57** of the fabric **56** causes a design **58** to be formed on the surface **57**. As described above, the speed of the laser beam **52** relative to the surface **57** of the fabric **56** is controlled within a predetermined range. In this embodiment, the specific movements and timing of the mirror **53** form the specific desired design **58** and maintain the Critical Operating Speed.

Referring now to FIG. **5**, there is illustrated a fifth embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. This fifth embodiment combines the methods of the third and fourth embodiments and is thus an even more economical method. The method utilizes the apparatus indicated generally at **60**. The apparatus **60** includes a laser **61** which generates a laser beam **62**. The laser **61** is in a stationary position.

The laser **61** is positioned to generate a laser beam **62** in the direction of a mirror **63**. A drive mechanism in the form of a mirror drive **64** is connected to the mirror **63**. The mirror drive **64** is adapted to cause movement of the mirror **63** in the vertical and horizontal directions, as shown by the arrows in the drawing. An electronic controller such as a computer **65** is connected to the mirror drive **64**. The computer **65** is adapted to provide a signal to the mirror drive **64** to control movement of the mirror **63**. The computer **65** is programmed by particular software (not shown) developed to control such movement.

In turn, the mirror **63** is positioned to deflect the laser beam **62** in the direction of a thin fabric **66**. The fabric **66** is positioned on a moving roll **67**. A drive mechanism in the form of a product drive **68** is connected to the moving roll **67**. The product drive **68** is adapted to cause rotation of the moving roll **67** and thus continuous movement of the fabric **66** in the horizontal direction, as shown by the arrows in the drawing.

In operation, the laser **61** is activated and generates the laser beam **62** in the direction of the mirror **63**. The mirror **63** deflects the laser beam **62** in the direction of the fabric **66**. The fabric **66** includes a surface **69**. The laser beam **62** contacts the surface **69** of the fabric **66**. The computer **65** provides a signal to the mirror drive **64**. In response to the signal, the mirror drive **64** causes movement of the mirror **63** which causes movement of the laser beam **62**. Movement of the laser beam **62** in contact with the moving surface **69** of the fabric **66** causes a design **70** to be formed on the surface **69**. As described above, the speed of the laser beam **62** relative to the surface **69** of the fabric **66** is controlled within a predetermined range. In this embodiment, the specific movements and timing of the mirror **63** and the product roll **67** are coordinated to form the specific desired design **70** and maintain the Critical Operating Speed. A sensor **71** can continuously detect the thickness of the fabric **66** prior to contact with the laser beam **62** and provide a signal to the computer **65** to adjust the relative speed.

Referring now to FIG. **6**, there is illustrated a sixth embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. The method utilizes the apparatus indicated generally at **80**. The apparatus **80** includes a laser **81** which generates a laser beam **82**. The laser **81** is in a stationary position.

The laser **81** is positioned to generate a laser beam **82** in the direction of a primary mirror **83**. A drive mechanism in the form of a primary mirror drive **84** is connected to the primary mirror **83**. The primary mirror drive **84** is adapted to cause movement of the primary mirror **83** in the horizontal direction, as shown by the arrow in the drawing. An electronic controller such as a computer **85** is connected to the primary mirror drive **84**. The computer **85** is adapted to provide a signal to the primary mirror drive **84** to control movement of the primary mirror **83**. The computer **85** is programmed by particular software (not shown) developed to control such movement.

By moving horizontally, the primary mirror **83** is positioned to deflect the laser beam **82** in the direction of a plurality of secondary mirrors **86**. A drive mechanism in the form of a secondary mirror drive **87** is connected to the secondary mirrors **86**. The secondary mirror drive **87** is adapted to cause movement of the secondary mirrors **86** in the vertical and horizontal directions, as shown by the arrows. Each secondary mirror **86** is positioned to deflect the laser beam **82** in the direction of a different portion of a thin fabric **88**, thereby spreading the laser beam **82** over the fabric **88**.

In operation, the laser **81** is activated and generates the laser beam **82** in the direction of the primary mirror **83**. The computer **85** provides a signal to the primary mirror drive **84**. In response to the signal, the primary mirror drive **84** causes movement of the primary mirror **83** in the horizontal direction. As the primary mirror **83** moves horizontally, the laser beam **82** is deflected against each of the secondary mirrors **86**. Each of the secondary mirrors **86**, in turn, deflects the laser beam **82** in the direction of a portion of the fabric **88**. The fabric **88** includes a surface **89**. The laser beam **82** contacts each portion of the surface **89** of the fabric **88**. The secondary mirror drive **87** causes movement of each of the secondary mirrors **86** in the vertical and horizontal directions, which causes a corresponding movement of the laser beam **82**. Movement of the laser beam **82** in contact with each portion of the surface **89** of the fabric **88** causes a plurality of designs **90** to be formed on the surface **89**. As described above, the speed of the laser beam **82** relative to the surface **89** of the fabric **88** is controlled within a predetermined range. In this embodiment, the specific movements and timing of the secondary mirrors **86** form the specific desired designs **90** and maintain the Critical Operating Speed.

Referring now to FIG. **7**, there is illustrated a seventh embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. The method utilizes the apparatus indicated generally at **100**. The apparatus **100** includes a laser **101** which generates a laser beam **102**. The laser **101** is in a stationary position.

The laser **101** is positioned to generate a laser beam **102** in the direction of a primary mirror **103**. A drive mechanism in the form of a primary mirror drive **104** is connected to the primary mirror **103**. The primary mirror drive **104** is adapted to cause movement of the primary mirror **103** in the horizontal direction, as shown by the arrow in the drawing. An electronic controller such as a computer **105** is connected to the primary mirror drive **104**. The computer **105** is adapted to provide a signal to the primary mirror drive **104** to control movement of the primary mirror **103**. The computer **105** is programmed by particular software (not shown) developed to control such movement.

By moving horizontally, the primary mirror **103** is positioned to deflect the laser beam **102** in the direction of a plurality of secondary mirrors **106**. A drive mechanism in the form of a secondary mirror drive **107** is connected to the secondary mirrors **106**. The secondary mirror drive **107** is adapted to cause movement of the secondary mirrors **106** in the vertical and horizontal directions, as shown by the arrows. Each secondary mirror **106** is positioned to deflect the laser beam **102** in the direction of a different portion of a thin fabric **108**, thereby spreading the laser beam **102** over the fabric **108**.

The fabric **108** is positioned on a moving roll **109**. A drive mechanism in the form of a product drive **110** is connected to the moving roll **109**. The product drive **110** is adapted to cause rotation of the moving roll **109** and thus continuous movement of the fabric **108** in the horizontal direction, as shown by the arrows in the drawing.

In operation, the laser **101** is activated and generates the laser beam **102** in the direction of the primary mirror **103**. The computer **105** provides a signal to the primary mirror drive **104**. In response to the signal, the primary mirror drive **104** causes movement of the primary mirror **103** in the horizontal direction. As the primary mirror **103** moves horizontally, the laser beam **102** is deflected against each of the secondary mirrors **106**. Each of the secondary mirrors **106**, in turn, deflects the laser beam **102** in the direction of a portion of the fabric **108**. The fabric **108** includes a surface **111**. The laser beam **102** contacts each portion of the surface **111** of the fabric **108**. The secondary mirror drive **107** causes movement of each of the secondary mirrors **106** in the vertical and horizontal directions, which causes a corresponding movement of the laser beam **102**. Movement of the laser beam **102** in contact with each portion of the surface **111** of the moving fabric **108** causes a plurality of designs **112** to be formed on the surface **111**. As described above, the speed of the laser beam **102** relative to the surface **111** of the fabric **108** is controlled within a predetermined range. In this embodiment, the specific movements and timing of the secondary mirrors **106** and the product roll **109** are coordinated to form the specific desired designs **112** and maintain the Critical Operating Speed. This embodiment employing a moving product roll in combination with a plurality of lenses to spread the laser beam over the fabric **108** is particularly economical. A sensor **113** can continuously detect the thickness of the fabric **108** prior to contact with the laser beam **102** and provide a signal to the computer **105** to adjust the relative speed.

Referring now to FIG. **8**, there is illustrated an eighth embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. The method utilizes the apparatus indicated generally at **120**. The apparatus **120** includes a laser **121** which generates a laser beam **122**. The laser **121** is in a stationary position. The laser beam **122** is directed toward a shutter **123**. The shutter **123** periodically interrupts the laser beam **122** by swinging back and forth perpendicular to the direction of the laser beam. A drive mechanism in the form of a shutter drive **124** is connected to the shutter **123**. The shutter drive **124** is adapted to cause the shutter **123** to swing back and forth. The shutter could also move in different directions to periodically interrupt the laser beam. Alternatively, the shutter could be constructed and operate similar to the shutter of a camera which periodically opens and closes.

An electronic controller such as a computer **125** is connected to the shutter drive **124**. The computer **125** is adapted to provide a signal to the shutter drive **124** to control movement of the shutter **123**. The computer **125** is programmed by particular software (not shown) developed to control such movement to interrupt the laser beam at desired intervals.

The laser **121** is positioned to generate a laser beam **122** past the shutter **123** in the direction of a thin fabric **126**. A drive mechanism in the form of a product drive **127** is connected to the fabric **126**. The product drive **127** is adapted to cause movement of the fabric **126** in the vertical and horizontal directions, as shown by the arrows in the drawing. An electronic controller such as a computer **128** is connected to the product drive **127**. The computer **128** is adapted to provide a signal to the product drive **127** to control movement of the fabric **126**. The computer **128** is programmed by particular software (not shown) developed to control such movement.

In operation, the laser **121** is activated and generates the laser beam **122** in the direction of the shutter **123**. The computer **125** provides a signal to the shutter drive **124**. In response to the signal, the shutter drive **124** causes movement of the shutter **123** to periodically interrupt the laser beam **122**. The laser beam **122** is directed past the shutter **123** in the direction of the fabric **126**. The fabric **126** includes a surface **129**. The laser beam **122** contacts the surface **129** of the fabric **126**. The computer **128** provides a signal to the product drive **127**. In response to the signal, the product drive **127** causes movement of the surface **129** of the fabric **126**. Movement of the surface **129** of the fabric **126** in contact with the laser beam **122**, in combination with the periodic interruption of the laser beam **122** by the shutter **123**, causes a discontinuous design **130** to be formed on the surface **129**.

Referring now to FIG. **9**, there is illustrated an ninth embodiment of a laser method of forming designs on thin fabrics and leathers in accordance with this invention. The method utilizes the apparatus indicated generally at **140**. The apparatus **140** includes a laser **141** which generates a laser beam **142**. The laser **141** is in a stationary position.

The laser beam **142** is directed through a lens **143**. The lens **143** serves to redirect the laser beam **142** in a manner that results in a more complex curved design. The lens **143** can be rotated for different redirections of the laser beam **142**, as shown by the arrow in the drawing. The lens **143** can also be moved laterally or can rotate on its vertical axis for different effects, such as to create thick or thin lines. A drive mechanism in the form of a lens drive **144** is connected to the lens **143**. The lens drive **144** is adapted to cause rotation of the lens **143**.

An electronic controller such as a computer **145** is connected to the lens drive **144**. The computer **145** is adapted to provide a signal to the lens drive **144** to control rotation of the lens **143**. The computer **145** is programmed by particular software (not shown) developed to control such rotation.

The laser beam **142** is then directed toward a shutter **146**. The shutter **146** periodically interrupts the laser beam **142** by swinging back and forth perpendicular to the direction of the laser beam. A drive mechanism in the form of a shutter drive **147** is connected to the shutter **146**. The shutter drive **147** is adapted to cause the shutter **146** to swing back and forth.

An electronic controller such as a computer **148** is connected to the shutter drive **147**. The computer **148** is adapted to provide a signal to the shutter drive **147** to control movement of the shutter **146**. The computer **148** is programmed by particular software (not shown) developed to control such movement to interrupt the laser beam at desired intervals.

The laser **141** is positioned to generate a laser beam **142** through the lens **143**, past the shutter **146**, and in the

direction of a thin fabric **149**. A drive mechanism in the form of a product drive **150** is connected to the fabric **149**. The product drive **150** is adapted to cause movement of the fabric **149** in the vertical and horizontal directions, as shown by the arrows in the drawing. An electronic controller such as a computer **151** is connected to the product drive **150**. The computer **151** is adapted to provide a signal to the product drive **150** to control movement of the fabric **149**. The computer **151** is programmed by particular software (not shown) developed to control such movement.

In operation, the laser **141** is activated and generates the laser beam **142** in the direction of the lens **143**. The computer **145** provides a signal to the lens drive **144**. In response to the signal, the lens drive **144** causes rotation of the lens **143** to the desired position. The laser beam **142** is directed through the lens **143** in the direction of the shutter **146**. The computer **148** provides a signal to the shutter drive **147**. In response to the signal, the shutter drive **147** causes movement of the shutter **146** to periodically interrupt the laser beam. The laser beam **142** is then directed past the shutter **146** in the direction of the fabric **149**. The fabric **149** includes a surface **152**. The laser beam **142** contacts the surface **152** of the fabric **149**. The computer **151** provides a signal to the product drive **150**. In response to the signal, the product drive **150** causes movement of the surface **152** of the fabric **149**. Movement of the surface **152** of the fabric **149** in contact with the laser beam **142**, in combination with the rotation of the lens **143** and the periodic interruption of the laser beam **142** by the shutter **146**, causes a design **153** to be formed on the surface **152**. The design **153** includes complex continuous and discontinuous design portions.

FIGS. **10** and **11** are drawings of laser designs formed on a thin fabrics and a leather in accordance with this invention. They demonstrate that a variety of different designs can be formed on a variety of different thin fabrics and leathers without carbonization or burn-through.

FIG. **10** illustrates a novel and attractive laser design formed on denim or jean fabric. This design includes thick and thin, continuous and discontinuous, and straight and curved lines. This new fashion concept is expected to be popular with consumers who purchase jeans.

A design formed on pig leather is illustrated in FIG. **11**. Such laser designs formed on leathers are unique in and of themselves since alternate processes to impart designs onto leather are rare and totally cost inefficient. This invention can thus be used to form designs onto vehicle leather interiors, jackets, boots, wallets and purses which are typically only differentiated by color.

In accordance with the provisions of the patent statutes, the principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

What is claimed is:

1. A method of using a laser for forming a design on a product selected from the group consisting of fabrics and leathers, comprising:

determining, for a specific material of the product, a maximum speed of said specific material relative to the laser, for a given laser power, that will result in a perceivable change for a given laser power, that will result in a perceivable change being formed to said product, and a threshold speed below which at least one of carbonization, undesired burn through or undesired melting of the material of the product will occur; and

contacting a surface of said product with the laser beam to form a design on said surface which changes the surface of the material, and controlling the speed of said laser beam relative to said surface to a range between said maximum speed and said threshold speed.

2. The method described in claim **1** wherein an electronic controller provides a signal to a drive mechanism to control said relative speed.

3. The method described in claim **2** wherein said drive mechanism controls movement of said laser.

4. The method described in claim **2** wherein said drive mechanism controls movement of said product.

5. The method described in claim **4** wherein said drive mechanism controls movement of said product on a roll.

6. A method described in claim **4** further comprising detecting a thickness of said product prior to said contact and providing a signal to said electronic controller to adjust said relative speed.

7. The method described in claim **2** wherein said electronic controller provides signals to a plurality of drive mechanisms to control said relative speed, and wherein said drive mechanisms control movement of a combination of devices selected from the group consisting of said laser, said product, a mirror and a lens.

8. The method described in claim **2** wherein said drive mechanism controls movement of a mirror.

9. The method described in claim **8** wherein said drive mechanism controls movement of a primary mirror and a plurality of secondary mirrors.

10. The method described in claim **2** wherein said drive mechanism controls movement of a lens.

11. The method described in claim **1** wherein said electronic controller is a computer programmed by software to control said relative speed.

12. The method described in claim **1** wherein said laser beam is modulated.

13. The method described in claim **1** wherein a shutter periodically interrupts said laser beam.

14. The method described in claim **1** wherein said fabrics are selected from the group consisting of cotton, rayon, nylon, wool, natural and artificial silk, acetate, flax, polyamide, lavsan, half wool, denim, raincoat fabric, woven and nonwoven canvas, and mixtures thereof.

15. The method described in claim **14** wherein said thin fabric is denim.

16. The method described in claim **1** wherein said leathers are selected from the group consisting of kid leather, lamb leather, pig leather, chamois leather, calf leather, suede and artificial leather.

17. The method described in claim **1** wherein said relative speed is between about 0.01 meters/second and about 1.5 meters/second.

18. The method described in claim **1** wherein said product is selected from the group consisting of rayon silk, nylon silk, raincoat fabric, and shirt and chemise fabric, and wherein said relative speed is between about 0.01 meters/second and about 1.5 meters/second.

19. The method described in claim **18** wherein said relative speed is between about 1.0 meters/second and about 1.4 meters/second.

20. The method described in claim **1** wherein said product is selected from the group consisting of 50% cotton/50% polyamide fabric and denim, and wherein said relative speed is between about 0.01 meters/second and about 1.5 meters/second.

21. The method described in claim **20** wherein said relative speed is between about 0.8 meters/second and about 1.2 meters/second.

22. The method described in claim 1 wherein said product is selected from the group consisting of artificial leather and pig leather, and wherein said relative speed is between about 0.01 meters/second and about 1.5 meters/second.

23. The method described in claim 22 wherein said relative speed is between about 0.03 meters/second and about 0.07 meters/second.

24. The method described in claim 1 wherein said surface is contacted by a laser beam generated by a CO_2 laser at a distance between about 0.08 meters and about 0.5 meters from said surface, wherein said laser has a radiation capacity between about 5 watts and about 150 watts, and wherein said laser beam has a wavelength of about 10.6 micrometers.

25. A method as in claim 1, wherein said contacting operates to form a design on said surface which causes a change in surface height of at least a portion of the surface.

26. A material marking apparatus, comprising:

a marking surface, adapted in operation to hold a material to be marked;

a laser device, producing a laser beam, said laser device being placed with its output facing said marking surface, and said laser beam being directed toward a location on said marking surface;

a drive mechanism, operating to change a position of said laser beam on said marking surface according to an applied command; and

a controller, connected to said drive mechanism and automatically producing said command to control said position of said laser beam on said marking surface, said controller controlling said drive mechanism to automatically control a speed of movement of said laser beam on said marking surface to a critical operating speed, said critical operating speed being dependent on the specific characteristics of the material being used, and being between a) a threshold speed where the laser beam will undesirably damage the material by one of undesirably fully penetrating the material, carbonization of the material, undesired melting or undesired burn-through of the material, and b) a maximum speed above which a desired imprint will not be formed on the material, to thereby change a surface of the material to a desired pattern on said material without undesired damage.

27. An apparatus as in claim 26 wherein said drive mechanism is a driving element coupled to move the laser, and wherein the controller includes a pre-stored program indicative of said desired pattern, said controller providing information to said driving element indicating with specific movement and timing information necessary to form said desired pattern based on said prestored program, said movement occurring at said critical operating speed.

28. An apparatus as in claim 26, further comprising a thickness sensor, operating to automatically sense a thickness of said material upon which said critical operating speed is determined, and providing an output to said controller, said controller including an element for operating to adjust said critical operating speed based on the thickness sensed by said sensor, and to produce said command to control said drive mechanism to move said laser beam on said material to said critical operating speed determined based on said characteristic which was automatically sensed.

29. An apparatus as in claim 26, wherein said critical operating speed is a speed that creates a design on said surface which causes a change in surface height of at least a portion of the surface.

30. An apparatus as in claim 26, further comprising a characteristic sensor, operating to automatically sense a characteristic of said material upon which said critical operating speed is determined, and providing an output to said controller, said controller including an element for operating to adjust said critical operating speed based on the characteristic sensed by said sensor, and to produce said command to control said drive mechanism to move said laser beam on said material to said critical operating speed determined based on said characteristic which was automatically sensed.

31. An apparatus as in claim 26 wherein said controller determines said critical operating speed as a function of all of a) a particular material being used, b) a thickness of the material, c) power and wavelength of the laser, d) distance between the laser and the material, and e) a particular design being formed.

32. An apparatus as in claim 26 wherein said drive mechanism is a driving element coupled to move the laser, and wherein the controller includes a pre-stored program indicative of said desired pattern, said controller providing information to said driving element indicating with specific movement and timing information necessary to form said desired pattern based on said prestored program, said movement occurring at said critical operating speed.

33. An apparatus as in claim 32 wherein said marking surface includes a roll having an outer surface including material thereon, and wherein said drive mechanism is a product drive connected to rotate said roll, said controller connected to said product drive to control a speed of movement of the roll.

34. An apparatus as in claim 33 wherein said drive mechanism further comprises a laser moving element, moving said laser relative to said roll, said controller controlling movement of said roll to control a first dimension of movement of the laser beam, and controlling a second dimension of movement of the laser beam by moving said laser.

35. An apparatus as in claim 33, further comprising a mirror, and said drive mechanism is also attached to said mirror, said mirror placed in a path of said laser beam to deflect said laser beam towards said marking surface, movement of said laser beam in a first dimension being controlled by movement of said roll and movement of said laser beam in a second direction being controlled by moving said mirror.

36. An apparatus as in claim 35, wherein said characteristic is thickness of the material, and said sensor is a thickness sensor.

37. An apparatus as in claim 35 wherein said mirror is a primary mirror and further comprising at least one secondary mirror, and at least one drive mechanism associated with said secondary mirror, said primary mirror controlling movement of said laser in a first direction and said secondary mirror controlling movement of the laser in the direction of a different position of the material, thereby spreading the laser relative to the material.

38. An apparatus as in claim 26 wherein said drive mechanism is a product drive coupled to move said marking surface, and wherein the controller includes a pre-stored program indicative of said desired pattern, said controller providing information to said driving element indicating with specific movement and timing information necessary to form said desired pattern based on said prestored program.

39. An apparatus as in claim 26 further comprising a mirror, positioned to receive said laser beam and to deflect said laser beam,

wherein said drive mechanism comprises a mirror drive, connected to said mirror and moving said mirror to

move in vertical and horizontal directions based on commands from said controller,

wherein said controller controls said mirror drive to move in said directions to move the laser beam on the marking surface at said critical operating speed to locations based on said stored program.

40. An apparatus as in claim **39** further comprising a second mirror operating to spread the laser beam over the marking surface.

41. An apparatus as in claim **26** further comprising a shutter, positioned in a path of the laser beam, and operating to periodically interrupt the laser beam from reaching said marking surface, said shutter including a first shutter portion which does not interrupt the laser beam, a second shutter portion which does interrupt the laser beam, and a movement mechanism which moves said shutter between positions where said first shutter portion and said second shutter portion are in the beam of light, periodically interrupt passage of the laser beam.

42. An apparatus as in claim **41** wherein said controller includes a program which indicates areas on the marking surface where portions of the patterns are not desired to be formed, and which commands said shutter to use said second portion to block said laser beam at said locations where said pattern portions are not being formed and commands said shutter to use said first portion to pass said laser beam at locations where said design is being formed.

43. An apparatus as in claim **26** further comprising a lens, coupled to receive an output of said laser beam, and coupling said laser beam toward said marking surface.

44. An apparatus as in claim **43** further comprising a drive mechanism, coupled to said lens, and operating to move said lens.

45. An apparatus as in claim **44** wherein said drive mechanism operates to rotate said lens, and laterally move said lens.

46. A material marking apparatus, comprising:

a marking surface, adapted in operation to hold a material to be marked;

a laser device, having an output beam which is directed toward a spot on said marking surface;

a drive mechanism, changing a relative position between said laser beam and said marking surface, according to an applied command;

a controller connected to said drive mechanism to command movement of said drive mechanism to a relative position between said marking surface and said laser beam, said controller controlling a speed between said marking surface and said laser beam to a critical operating speed within a predetermined range between a) a threshold speed where the laser beam results in undesired damage to the material and b) a maximum speed where the laser beam does not produce altering to a surface of the material, to thereby form a change to said material without undesirably damaging said material;

a material sensing element, operating to automatically sense a characteristic of said material which affects a propensity of said material to be altered by said laser beam; and

said controller also being responsive to said characteristic that is sensed by said material sensing element, and said controller altering said critical operating speed based on changes in said material characteristic, to control said laser to alter the surface of the material.

47. An apparatus as in claim **46**, wherein said critical operating speed is a speed that creates a design on said surface which causes a change in surface height of at least a portion of the surface, and wherein said change to said material is a change to said surface height.

48. An apparatus as in claim **46** wherein said material sensing element is a thickness sensor and said characteristic is thickness.

49. An apparatus as in claim **48** wherein said computer controls said drive mechanism to maintain a speed automatically controlling said position of said laser beam on said marking surface, said controller controlling a speed of movement of said laser beam on said marking surface within a predetermined range, said speed of movement controlled to a critical operating speed, said critical operating speed being between a threshold speed where the laser beam damages the material by one of fully penetrating the material, carbonization of the material, melting or burn-through of the material, and a maximum speed beyond which a desired imprint will not be formed on the material, to thereby print a desired pattern on said material.

50. A method of forming a pattern on a material, comprising:

providing a laser beam which shines on a material to be processed;

moving a position of said laser beam relative to said material;

sensing a characteristic of said material; and

using a computer to adjust a speed of said laser beam relative to said material, said computer maintaining said speed at a critical operating speed that is between a maximum speed beyond which a desired pattern will not be formed on said material, and a minimum operating speed below which undesired damage to the material will result, and said computer responsive to said characteristic sensed by said sensing to determine said critical operating speed at which the laser beam is driven relative to the material, whereby an operation on a first material with a first characteristic is operated at a different relative speed than an operation on a second material with a second characteristic different than said first characteristic.

51. A method as in claim **50** wherein said characteristic being sensed is thickness, wherein said characteristic is automatically sensed, and wherein said different operating speed is used for a material having a first thickness compared with a material having said second thickness.

52. A method as in claim **50**, wherein said critical operating speed is a speed that creates a design on said surface which causes a change in surface height of at least a portion of the surface, and further comprising changing a surface height of said material by scanning said laser at said critical operating speed.

53. A method of forming a discontinuous design on a material, comprising:

providing a material and a laser beam;

selectively allowing said laser beam to pass to said material, based on an applied command;

selectively moving said laser beam relative to the material based on an applied command; and

storing a pattern forming program in an automatic controller, said pattern forming program including information indicative of a discontinuous pattern to be formed on the material, said discontinuous pattern including at least two unconnected parts, and producing said commands for said allowing said laser beam to pass to said material, and to selectively move said laser beam relative to said material, said commands includ-

ing a first command which commands said laser beam to pass to said material during times when it is desired to form said design on said material, and a second command which commands no laser beam during times when it is desired to form the discontinuity in the pattern, to thereby form a pattern which has discontinuous portions further comprising using said controller to determine a desired speed of relative motion between said laser beam and said material based on characteristics of the material being used, said speed being a critical operating speed which is between a) a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting or burn-through of the material, and b) a maximum speed above which a desired imprint will not be formed on the material.

54. A method as in claim **53** further comprising using said controller to determine a desired speed of relative motion between said laser beam and said material based on characteristics of the material being used, said speed being a critical operating speed which is between a) a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting or burn-through of the material, and b) a maximum speed above which a desired imprint will not be formed on the material.

55. A method as in claim **54** wherein said movement is effected by moving an output of the laser beam.

56. A method as in claim **53**, further comprising changing a surface height of said material by moving said laser beam on said surface.

57. A discontinuous material scribing apparatus, comprising:

a marking surface;

a laser producing a laser beam;

a drive mechanism;

a laser selecting device, located between said laser beam and said marking surface, and having at least two positions, a first position in which said laser beam is unobstructed and impinges on said marking surface and a second position in which said laser beam is prevented by said laser selecting device from reaching said surface; and

a controller, controlling at least said drive mechanism and said laser selecting device, said controller storing a stored program indicating a desired pattern to be formed on said marking surface, said desired pattern including at least a first design portion which extends from a first part to a second part, a second design portion which does not connect with said first design portion, said second design portion extending from a third part, unconnected to said second part, and said second design portion extending to a fourth part, said controller controlling said drive mechanism and said laser selecting device, to:

move said drive mechanism to said first part and move said laser selecting device to said first position so said laser beam shines on said material;

then move said laser beam to said second part;

then move said laser selecting device to said second position so that said laser beam is prevented from reaching said material;

then move said drive mechanism to said third part;

then move said laser selecting device to said first position so that said laser beam shines on said material; and

then move said drive mechanism to said fourth part to end a discontinuous part of the pattern wherein said controller also controls a speed of said drive mechanism and said critical operating speed being dependent on characteristics of the specific material being used and characteristics of a design being formed.

58. An apparatus as in claim **57**, wherein said controller determines said critical operating speed as a function of all of a) a material material being used, b) a thickness of the material, c) power and wavelength of the laser, d) distance between the laser and the material, and e) a particular design being formed.

59. A device for forming a pattern on a material, comprising:

a marking surface, adapted in operation to hold a material to be marked;

a laser device, producing a laser beam, said laser device being placed with its output facing said marking surface, and said laser beam being directed toward a location on said marking surface;

a drive mechanism, operating to change a position of said laser beam on said marking surface according to an applied command;

an optical beam width adjusting element, coupled between an output of said laser beam and said marking surface, and operating to adjust an effective width of marking of the laser beam, to effectively adjust an effective width of a pattern portion that is formed by the laser beam on said marking surface; and

a controller, operating according to a stored sequence which includes information indicating a desired pattern to be formed on said marking surface, said controller producing an output which controls said optical beam width adjusting device to adjust the width of said pattern portion according to a width stored in said stored sequence, said stored sequence including a first design portion which has a thinner width, said controller operating to control said optical beam width adjusting device to command the formation of a thinner width pattern portion responsive to said first design portion, and said stored sequence including a second design portion which commands the formation of a thicker width pattern portion, said controller operating to control said optical beam adjusting device to command said thicker width pattern portion responsive to said second design portion.

60. A device as in claim **59**, wherein said controller controls said laser to change a surface height of said material by moving said laser beam on said surface.

61. A device as in claim **59** wherein said controller also controls a relative speed between said marking surface and said laser beam, said relative speed being a critical operating speed which is between a) a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting or burn-through of the material, and b) a maximum speed above which a desired change will not be formed on the material, and said critical operating speed being dependent on characteristics of the material being used.

62. A device as in claim **61** wherein said optical beam width adjusting element includes a lens.

63. A device as in claim **62** wherein said lens includes a moveable portion, moving to change a position of said lens, and a controllable drive mechanism, controlling movement of said lens, said controller commanding said moveable drive mechanism to move in a way which varies a width of the optical beam responsive to said stored sequence.

64. A device as in claim **61** wherein said optical beam width adjusting element includes a moveable mirror.

65. A device as in claim **64** wherein said moveable mirror includes a moving element, connected to said moveable mirror and controlling said moveable mirror in a way to increase an optical beam width of its output.

66. A device as in claim **65**, wherein said beam width is increased by scanning the mirror alternately in directions perpendicular to a desired width.

67. A device as in claim **65** further comprising a plurality of additional mirrors, optically coupled to said laser beam, and moving to adjust a position of said laser beam.

68. A method of forming a design on a material, comprising:

providing a laser device and a material holding surface relative to one another;

selectively operating the laser device, such that an output of the laser device impinges on the material holding surface;

moving a position of said output of said laser device on said material holding surface;

storing a program indicating a desired pattern to be printed on a material which will be placed on the material holding surface, said program indicating said desired design including at least a first stored part indicating a thicker portion area of the design, and a second stored part indicating a thinner portion area of the design; and

controlling a movement between said laser beam and said material holding surface according to the stored program, including controlling an output of said laser beam to form a thicker portion of the design at the first portion and to form a thinner portion of the design at the second portion.

69. A method as in claim **68** further comprising controlling a speed of said laser beam on said material to a critical operating speed which is between a) a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting or burn-through of the material, and b) a maximum speed above which a desired change not be formed on the material, and said critical operating speed being dependent on characteristics of the material being used.

70. A method as in claim **69** wherein said controlling an output width of said laser beam comprises providing a mirror, and commanding said mirror to scan its movement in a way which spreads the beam on the material.

71. A method as in claim **69** wherein said controlling an output width of said laser beam comprises moving a moveable lens in a way which adjusts an effective beam width on the material.

72. A method as in claim **71** wherein said material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

73. A method of forming a pattern on a material, comprising:

obtaining a specific material to be processed;

obtaining a laser to be used to mark said material;

determining, for said specific material, a threshold speed of scanning for said laser, below which undesired damage to the material will be caused;

determining, for said specific material, a maximum speed above which a desired physical change to the material will not be formed; and

commanding the laser to operate on the material to physically change the material in the form of a pattern on the material, by moving a position of the laser beam on the material at a process operating speed between said threshold speed and said maximum speed which are determined for the specific material.

74. A method as in claim **73** wherein said undesired damage to the material includes at least one of carbonization, melt through or undesired burn through.

75. A method as in claim **73** wherein said process operating speed is determined by considering all of at least a particular material, a thickness of the material, characteristics of the laser beam and a particular design to be formed.

76. A method as in claim **75** wherein said forming comprises unrolling material from a roll having an outer surface including material thereon by rotating said roll, said process operating speed being, at least partly, a speed of movement of said roll.

77. A method as in claim **76** further comprising also moving said laser relative to said roll, and controlling movement of said roll to control a first dimension of movement of the laser beam, and controlling a second dimension of movement of the laser beam by moving said laser.

78. A method as in claim **76**, further comprising using a mirror to deflect said laser beam towards said material, and controlling movement of said laser beam in a first dimension by movement of said roll and movement of said laser beam in a second direction by movement of said mirror.

79. A method as in claim **78** further comprising at least one secondary mirror to control movement of said laser in a direction different from a direction of control by a primary mirror, thereby forming a thicker part of a pattern by effectively spreading the laser relative to the material.

80. A method as in claim **78** further comprising using another mirror to move the laser beam in a way that effectively spreads the laser beam over the marking surface.

81. A method as in claim **73** further comprising automatically determining a thickness of said material; and

wherein said process operating speed is determined at least partly as a function of said sensed thickness.

82. A method as in claim **73** wherein said maximum and minimum speed determining comprises determines said process operating speed as a function of all of a) a particular material being used, b) a thickness of the material, c) power and wavelength of the laser, d)distance between the laser and the material, and e) a particular design being formed.

83. A method as in claim **73** wherein said moving comprises moving the laser, and further comprising storing a prestored program indicative of said desired pattern, and providing information to indicate specific movement and timing information necessary to form said desired pattern based on said prestored program, said movement occurring at said process operating speed.

84. A method as in claim **73** wherein said moving comprises moving said material, and further comprising storing a pre-stored program indicative of said desired pattern, and providing information to indicate specific movement and timing information necessary to form said desired pattern based on said prestored program, said movement occurring at said process operating speed.

85. A method as in claim **73** further comprising using a mirror to deflect said laser beam to a desired position by commanding said mirror to move in vertical and horizontal directions at said process operating speed to locations based on said stored program.

86. A method as in claim **73**, further comprising a automatically sensing a characteristic of said material upon which said critical operating speed is determined, and using

said automatically sensed characteristic to adjust said process operating speed,

to produce said command to control said drive mechanism to move said laser beam on said material to said critical operating speed determined based on said characteristic which was automatically sensed.

87. A method as in claim **86**, wherein said characteristic is thickness of the material.

88. A method as in claim **73** further comprising periodically interrupting the laser beam prior to its reaching said material.

89. A method as in claim **88** further comprising storing a program which indicates areas on the marking surface where portions of the patterns are not desired to be formed, and which commands blocking said laser beam at said locations where said pattern portions are not being formed and commands passing said laser beam at locations where said design is being formed.

90. A method as in claim **73** further comprising using a lens to receive an output of said laser beam, and couple said laser beam toward said marking surface.

91. A method as in claim **90** further comprising moving said lens to change a position of the laser beam.

92. A method as in claim **91** further comprising rotating said lens, and laterally moving said lens.

93. A method as in claim **73**, wherein said forming comprises controlling said laser to change a surface height of said material by moving said laser beam on said surface.

94. A method of forming a pattern on a fabric material, comprising:

experimenting on a plurality of different kinds of fabric materials to determine a critical operating speed for each material, said critical operating speed being one where a laser beam forms a desired pattern on said material without damaging the material in an undesired way, said critical operating speed being between a maximum speed at which a desired change to the material is not formed in the material, and a minimum speed below which undesired damage is caused to the material;

determining a specific material to be used;

determining a critical operating speed from the previously-obtained critical operating speeds determined by said experimenting; and

forming a pattern on the material by illuminating the laser beam on the material and moving the laser beam on the material at the selected critical operating speed.

95. A method as in claim **94** further comprising using an automatic characteristic sensor to automatically determine a characteristic of said material; and

automatically determining said process operating speed based on at least an output of said automatic characteristic sensor.

96. A method as in claim **95** wherein said automatic characteristic sensor is a thickness sensor and said process operating speed is determined at least partly as a function of the automatically sensed thickness.

97. A method as in claim **94** wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

98. A laser apparatus as in claim **94**, wherein said change is one of a physical change or a chemical change or both a chemical change and a physical change.

99. A method of altering characteristics of a material, comprising:

determining at least one characteristic of the material, said at least one characteristic being of a kind which affects a propensity of the material to be physically altered by a radiation source;

using said at least one characteristic to determine a radiation source power and speed of movement of an output of the radiation source over the material that will cause a desired structural change of the material without undesired damage to the material;

storing information in a controller indicating a desired pattern to be formed on said material; and

using said controller to control said radiation source according to said determined radiation source power and speed of movement determined in said using and according to said stored information indicating the desired pattern.

100. A method as in claim **99** further comprising an initial step of modeling a plurality of said materials using said characteristics to determine said power and speed from the modeled characteristics.

101. A method as in claim **99** wherein a part of said stored information indicating the desired pattern includes an indication of a width of a portion of the desired pattern to be formed on said material, and further comprising altering said width according to said stored information.

102. A method as in claim **99** wherein said determining characteristics of the material comprises automatically determining said characteristics.

103. A method as in claim **102** wherein said characteristic includes thickness of the material, and the automatic detecting is carried out by a thickness detector.

104. An apparatus for forming a pattern on a material, comprising:

a laser, producing a laser beam output;

an element holding device, which in operation, holds a material on which a pattern is to be formed;

a laser beam moving element, effecting a movement of said laser beam on said material when said material is located on said element holding device; and

an automated controller, which stores a pre-stored series of information indicative of pattern positions will form the pattern on said material, and also obtaining information about said material, and determining a critical parameter of said laser beam relative to said material, said critical parameter being a parameter allowing said pattern to be formed by physical altering of a surface of said material without undesired damage to the material, said automated controller controlling said laser and moving speed according to said information indicative of said critical parameter, and also controlling the position of the laser beam according to the prestored series of information to form a pattern on the surface without undesired damage to the surface.

105. An apparatus as in claim **104** wherein said critical parameter is a critical operating speed of the laser beam relative to said holding device.

106. An apparatus as in claim **104** wherein said moving device includes at least one movable mirror in the path of laser beam output, deflecting the laser beam to the material.

107. An apparatus as in claim **104** wherein said material is a fabric material.

108. An apparatus as in claim **107** wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

109. An apparatus as in claim **104** wherein the material is an undyed material.

110. An apparatus as in claim **104** wherein said laser beam moving element is a moving device on the element holding device.

111. An apparatus as in claim **104** wherein said laser beam moving element is a moving element on the laser.

112. A method of producing a design on a material, comprising:

producing a focused beam of radiation, said focused beam being directed to a location where a material to be altered is adapted to be located;

storing pre-stored data which represents pattern portions to be formed to represent a pattern to be inscribed on said material;

determining a critical parameter for said beam of radiation on said material based on characteristics of the material being used, and based on a determined maximum speed for the material being used at which less-than-desired change will be caused to said material, resulting in an imperfect pattern being formed on said material, and a determined minimum operating speed for the material being used at which undesired damage to the material will be formed; and

commanding said beam of radiation to move at the critical parameter to locations indicated by said stored pattern portion.

113. A method as in claim **112** wherein said beam of radiation is a laser beam and said critical parameter is a critical operating speed of the laser beam relative to the material.

114. A method as in claim **112** wherein said information includes at least first and second discontinuous pattern segments which include said desired pattern including at least a first design portion which extends from a first part to a second part, a second design portion which does not connect with said first design portion, said second design portion extending from a third part, unconnected to said second part, and said second design portion extending to a fourth part,

wherein said commanding said beam of radiation comprises:

moving said beam of radiation to said first part so said laser beam shines on said material to begin said first discontinuous pattern segment;

then moving said beam of radiation to said second part at said critical operating speed for said material;

then interrupting said beam of radiation so that said beam of radiation is prevented from reaching said material to thereby end said first discontinuous pattern segment;

then commanding movement of said beam of radiation to said third part;

then starting said beam of radiation when it is located at said third part to begin said second discontinuous pattern segment;

then moving said beam of radiation to said fourth part at said critical operating speed to end the second discontinuous pattern segment.

115. A method as in claim **114** wherein said beam of radiation is a laser beam.

116. A method as in claim **112** wherein said beam of radiation is a laser beam.

117. An apparatus for scribing a pattern onto a material using a laser, comprising:

a numerically controlled laser system including a working surface on which a material to be processed is adapted to placed, a laser portion which produces a laser output and directs said laser output toward said working surface, and a numerical control portion which stores control information commanding motion between said laser output and said working surface, said numerical control portion storing information indicating: (1) for a specific kind of material being used, information indicating a critical operating speed at a specified laser power, said critical operating speed being between a maximum speed that is too fast to cause a desired change to a surface of the material and a minimum speed, below which undesired damage to the material can occur, and (2) information indicative of a plurality of desired pattern segments which together form the desired pattern to be formed, said numerically controlled laser system responsive to said desired pattern segments to move the laser beam over the material in areas corresponding to said desired pattern segments and to thereby form the pattern on the material.

118. An apparatus as in claim **117** further comprising a laser blocking element with a first position in which the laser beam is allowed to pass, and a second position in which the laser beam is not allowed to pass, and wherein said numerically controlled laser system includes at least information indicative of one discontinuous area where a line segment ends at one location and begins at a second location spaced from said one location and which commands said laser blocking element to allow said laser beam to pass at said one location, commands said laser blocking element to not allow said laser beam to pass at said area between said one location and said second location and commands said laser blocking element to allow said laser beam to pass at said second location.

119. A laser apparatus as in claim **117**, wherein said change is a physical change.

120. A method of selectively altering portions of a material to form a desired pattern on the material, comprising:

determining a pattern to be formed on the material;

determining specific characteristics of the material on which the pattern is to be formed;

determining special operational parameters for the material with its specific characteristics, said special operational parameters which allow a focused beam of radiation to form a pattern in the material which changes the material without undesirably damaging the material; and

forming a pattern on said material using the special operational parameters.

121. A method as in claim **120**, wherein said focused beam of radiation is a laser beam.

122. A method as in claim **120**, wherein said determining comprises determining a critical operating speed for said beam of radiation on said specific material based on characteristics of the specific material being used, and based on a determined maximum speed for the material beyond which a desired physical change to a surface of the material will not be formed, and a determined minimum operating speed for the material being used at which damage to the material will be formed.

123. A method as in claim **120**, wherein said material is a fabric material.

124. A method as in claim **123**, wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

125. A method of producing a discontinuous design on a material, comprising:

storing information which represents pattern portions to be formed to represent a pattern to be inscribed on said material, said information includes at least first and second discontinuous pattern segments which include

said desired pattern including at least a first design portion which extends from a first part to a second part, a second design portion which does not connect with said first design portion, said second design portion extending from a third part, unconnected to said second part, and said second design portion extending to a fourth part;

producing a focused beam of radiation;

determining a critical parameter for said beam of radiation on said material based on characteristics of the material being used, by determining a parameter range between a) a first parameter where a desired change to a surface of the material will not be formed, and b) a second parameter where which an imperfect pattern will be formed on said material, and a determined minimum operating speed for the material being used at which damage to the material will be formed;

moving said beam of radiation to said first part so said beam of radiation shines on said material to begin said first discontinuous pattern segment;

then moving said beam of radiation to said second part using said critical parameter for said material;

then interrupting said beam of radiation so that said beam of radiation is prevented from reaching said material to thereby end said first discontinuous pattern segment;

then commanding movement of said beam of radiation to said third part;

then starting said beam of radiation when it is located at said third part to begin said second discontinuous pattern segment;

then moving said beam of radiation to said fourth part using said critical parameter to end the second discontinuous pattern segment.

126. A method of selectively altering portions of a material to form a desired pattern on the material, comprising:

determining a pattern to be formed on a surface of the material;

determining specific characteristics of the material on which the pattern is to be formed;

determining special operational parameters for the material with its specific characteristics, said special operational parameters which allow a focused beam of radiation to form a pattern in the surface of the material, of a type which causes a change in a height of at least a portion of said surface; and

forming a pattern on said surface of said material which changes the height of the surface of the material, using said special operational parameters determined by said determining special operational parameters.

127. A method as in claim **126**, wherein said special operational parameters are a critical operating speed, said critical operating speed being between a) a threshold speed where the laser beam will damage the material by one of undesirably fully penetrating the material, carbonization of the material, melting or burn-through of the material, and b) a maximum speed above which a desired imprint will not be formed on the material, to thereby print a desired pattern on said material.

128. An pattern forming apparatus operating to form a pattern on a flexible material, comprising:

a marking surface, adapted in operation to hold a specific material to be marked;

a laser device, producing a laser beam, said laser device being placed with its output facing said marking surface, and said laser beam being directed toward a location on said marking surface;

a drive mechanism, operating to change a position of said laser beam on said marking surface according to an applied command; and

a controller, determining, for said specific material, a threshold parameter for said laser within which undesired damage to the material will not be caused and within which a desired physical or chemical change to a surface of the material will be caused, said controller controlling said laser device to form a pattern on the material by moving a position of the laser beam on the material using said parameter determined for the specific material.

129. An apparatus as in claim **128**, further comprising a characteristic sensor, operating to automatically sense a characteristic of said material upon which said critical parameter is determined, and providing an output to said controller, said controller including an element for operating to adjust said critical parameter based on the characteristic sensed by said sensor, and to produce a command to control according to said parameter.

130. An apparatus as in claim **129**, wherein said characteristic is thickness of the material, and said sensor is a thickness sensor.

131. A pattern forming apparatus as in claim **128**, wherein said parameter is one which controls said laser to change a surface height of said material by moving said laser beam on said surface.

132. A pattern forming apparatus as in claim **128**, wherein said material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture of these materials.

133. An apparatus as in claim **128** wherein said critical parameter is critical operating speed range of said laser relative to said material, beyond which a desired physical change to a surface of the material will not be formed and below which undesired damage to a surface of the material will be caused.

134. An apparatus as in claim **128**, wherein said material is a fabric material.

135. A pattern forming apparatus operating to form a pattern on a material, comprising:

a marking surface, adapted in operation to hold a specific material to be marked;

a laser device, producing a laser beam, said laser device being placed with its output facing said marking surface, and said laser beam being directed toward a location on said marking surface;

a drive mechanism, operating to change a position of said laser beam on said marking surface according to an applied command; and

a controller, determining, for said specific material, a threshold parameter for said laser within which less damage will occur to the material than would occur from chemical dyeing process, and within which a desired change to a surface of the material will be caused, and, said controller controlling said laser device to form a pattern on the material by moving a position of the laser beam on the material using said parameter determined for the specific material.

136. An apparatus as in claim **135** wherein said threshold parameter is critical operating speed range of said laser relative to said material, beyond which a desired physical change to a surface of the material will not be formed and below which more damage to the material will be caused than would be caused by chemical dyeing processes.

137. An apparatus as in claim **135**, wherein said material is a fabric material.

138. An apparatus as in claim **137**, wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

139. An apparatus as in claim **137**, wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

140. An apparatus as in claim **135**, wherein said threshold parameter is a parameter that creates a design on said surface which causes a change in surface height of at least a portion of the surface, and wherein said change to said material is a change to said surface height.

141. A method of selectively altering portions of a material to form a desired pattern on the material, comprising:

determining a pattern to be formed on the material;

determining specific characteristics of the material on which the pattern is to be formed;

determining special operational parameters for the material with its specific characteristics, said special operational parameters which allow a focused beam of radiation to cause a chemical change in a surface of the material that causes a pattern which can be seen to be formed in the material without undesirably damaging the material; and

forming a pattern on said material using the special operational parameters.

142. A method as in claim **141**, wherein said material is a fabric material.

143. A method as in claim **142**, wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

144. A method as in claim **141**, wherein said threshold parameter is a parameter that creates a design on said surface which causes a change in surface height of at least a portion of the surface, and wherein said change to said material is a change to said surface height.

145. A method as in claim **141**, wherein said threshold parameter is critical operating speed range of said laser relative to said material, beyond which the desired chemical change to a surface of the material will not be formed and below which undesired damage to the material will be caused.

146. An apparatus for forming a pattern on a material, comprising:

a CO_2 laser, producing a laser beam output;

an element holding device, which in operation, holds a material on which a pattern is to be formed;

a laser beam moving element, effecting a movement of said laser beam on said material when said material is located on said element holding device; and

an automated controller, which stores a pre-stored series of information indicative of pattern positions will form the pattern on said material, and also obtaining information about said material, and determining a critical parameter of said laser beam relative to said material, said critical parameter being a parameter allowing said pattern to be formed by altering of a surface of said material without undesired damage to the material, said automated controller controlling said laser and moving speed according to said information indicative of said critical parameter, and also controlling the position of the laser beam according to the prestored series of information stored program to form a pattern on the surface without undesired damage to the surface.

147. An apparatus as in claim **146** wherein said critical parameter is critical operating speed range of said CO_2 laser relative to said material, beyond which a desired physical change to a surface of the material will not be formed and below which undesired damage to a surface of the material will be caused.

148. An apparatus as in claim **147**, wherein said material is a fabric material.

149. An apparatus as in claim **148**, wherein said fabric material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

150. An apparatus as in claim **146**, wherein said critical parameter is a parameter that creates a design on said surface which causes a change in surface height of at least a portion of the surface, and wherein said change to said material is a change to said surface height.

151. A method of forming a desired pattern on an undyed fabric type material, comprising:

determining a pattern to be formed on the material;

determining specific characteristics of the material on which the pattern is to be formed;

determining special operational parameters for the material with its specific characteristics, said special operational parameters which allow a focused beam of radiation to form a pattern in the material which can be seen, without undesirably damaging the material; and

forming a pattern on said material using the special operational parameters.

152. A method as in claim **151**, wherein said material is one of denim, leather, cotton, rayon, nylon, wool, silk, or a mixture thereof.

153. A method as in claim **151**, wherein said pattern is formed by changing a physical structure of the material using said focused beam of radiation.

154. A method as in claim **153**, wherein said focused beam of radiation is a laser beam.

* * * * *

EXHIBIT 2

US006664505B2

(12) **United States Patent**
Martin

(10) **Patent No.: US 6,664,505 B2**
(45) **Date of Patent: Dec. 16, 2003**

(54) **LASER PROCESSING OF MATERIALS USING MATHEMATICAL TOOLS**

(75) Inventor: **Clarence H Martin**, Gahanna, OH (US)

(73) Assignee: **TechnoLines LLC**, Toledo, OH (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 88 days.

(21) Appl. No.: **09/730,497**

(22) Filed: **Dec. 5, 2000**

(65) **Prior Publication Data**

US 2001/0037999 A1 Nov. 8, 2001

Related U.S. Application Data

(60) Provisional application No. 60/169,096, filed on Dec. 6, 1999.

(51) **Int. Cl.**[7] **B23K 26/00**

(52) **U.S. Cl.** **219/121.85**; 219/121.68; 700/166

(58) **Field of Search** 219/121.61, 121.68, 219/121.69, 121.85; 345/441; 700/166

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,473,736 A * 12/1995 Young
5,831,633 A * 11/1998 Van Roy
5,990,444 A * 11/1999 Costin 219/121.69
6,059,391 A * 5/2000 Fulkerson et al.
6,495,237 B1 * 12/2002 Costin
6,526,158 B1 * 2/2003 Goldberg

OTHER PUBLICATIONS

Wegner et al., "Fractals for Windows", 1992, Waite Group Press, pp. 128–140 and 265–268.*

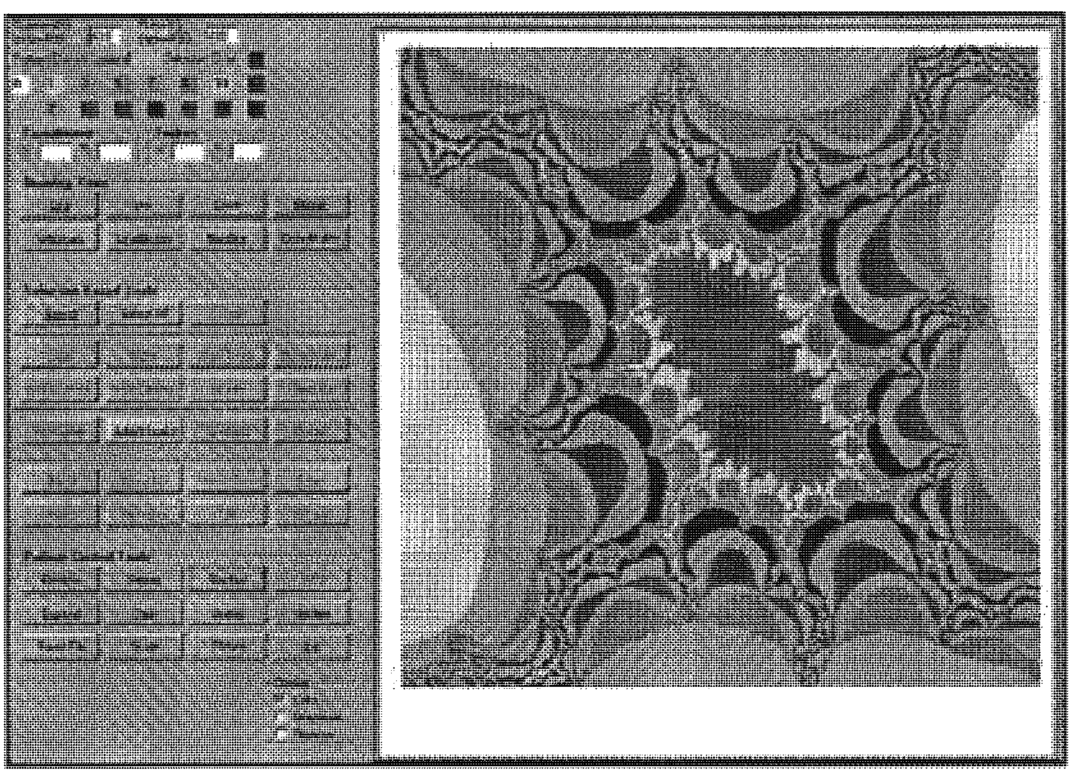
* cited by examiner

Primary Examiner—Geoffrey S. Evans
(74) *Attorney, Agent, or Firm*—Scott C. Harris, Es

(57) **ABSTRACT**

A system of forming an image using mathematical tools. The images formed using any of the set of mathematical tools, which can be modular level sets, fractals, or cellular automata, or any other modular level set tool. Whenever tool is used, but parameters associated with the values in that tool can be set. This allows producing a number of different functions. The output of the tool is an image, which each pixel of the image having a color and each color representing some change that is to be carried out to the material being processed. The material being processed can be a textile material or denim for example. The processing device can be a laser which produces an output whose value is dependent on the different colors, with each color representing a power output or energy density per unit time specific to that color.

118 Claims, 22 Drawing Sheets



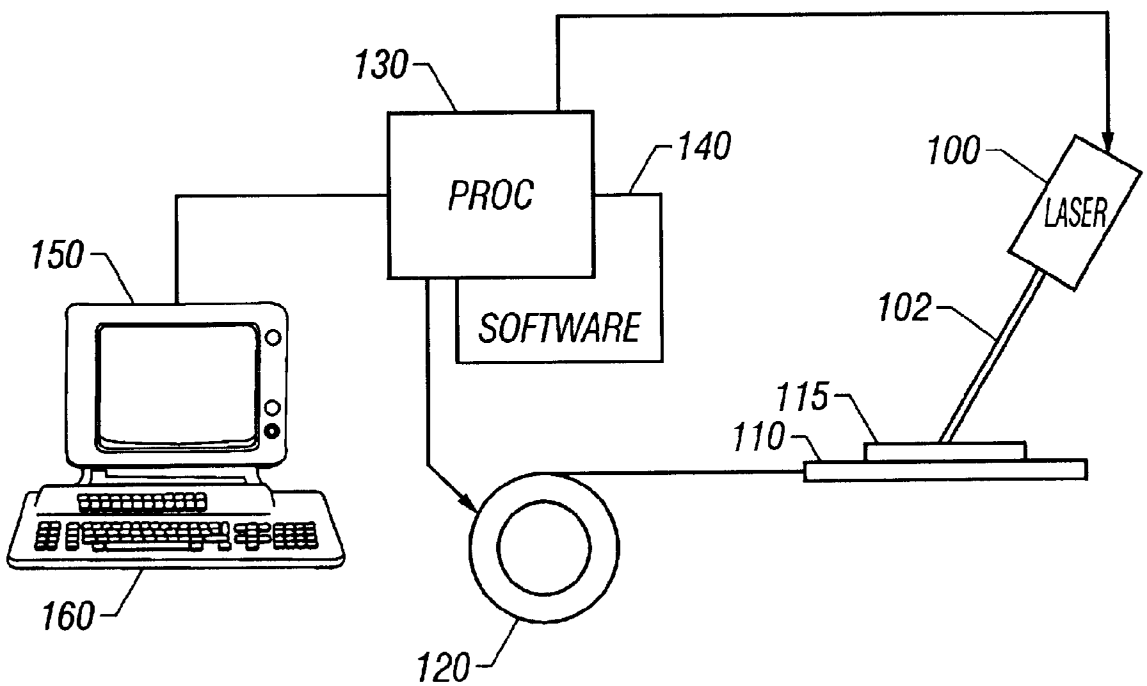


FIG. 1

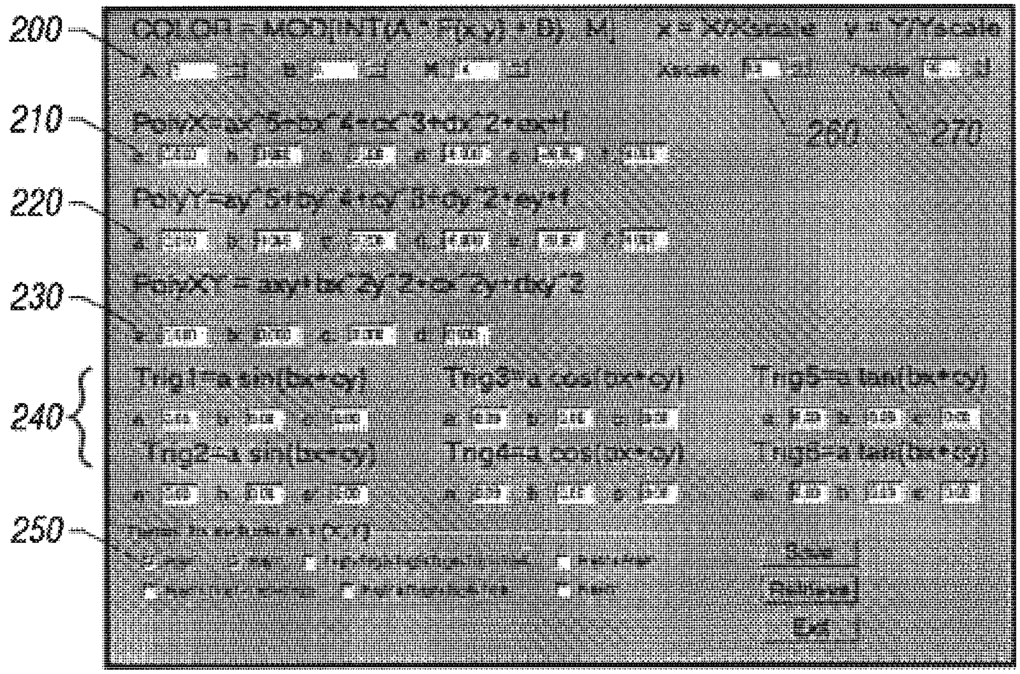

200
210
220
230
240
250
260
270
COLOR = MOD[INT(A * F(x,y) + B), M]
x = X/Xscale y = Y/Yscale
Xscale
Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)
Save
Retrieve
Exit

FIG. 2A

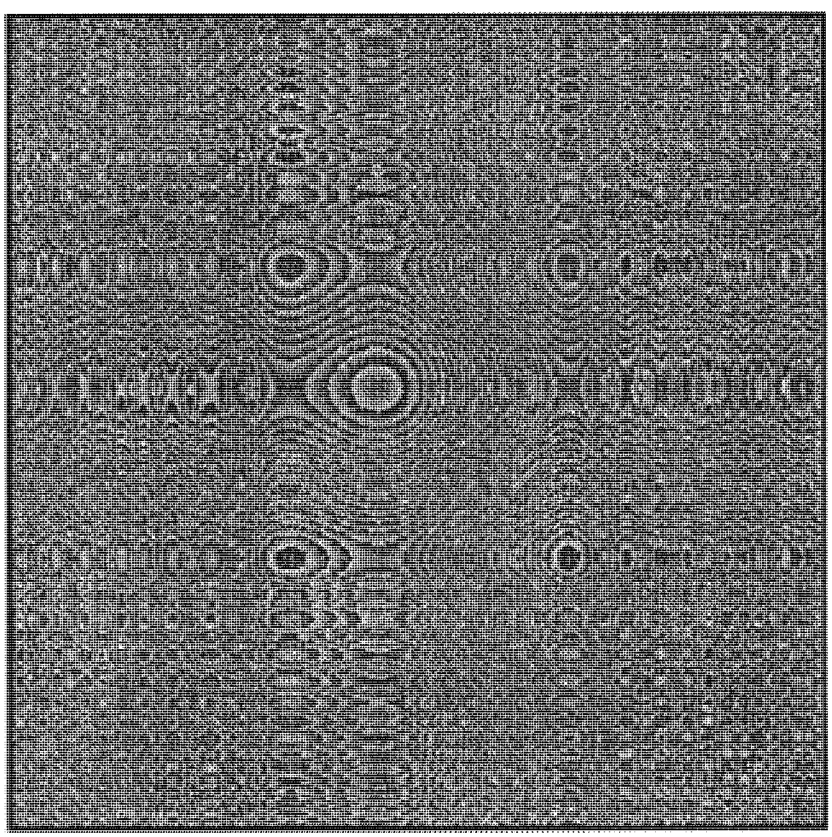


FIG. 2B

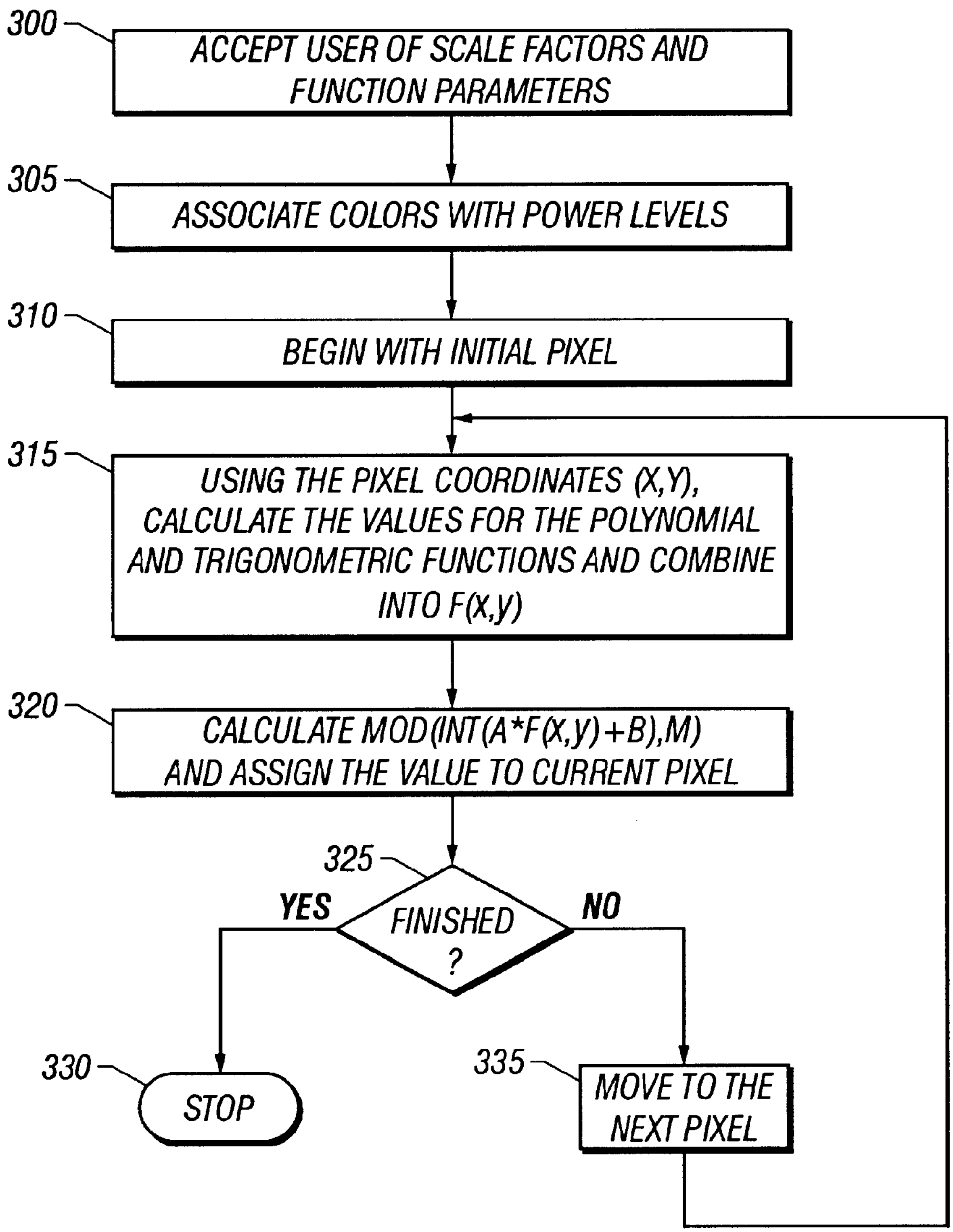

300
ACCEPT USER OF SCALE FACTORS AND FUNCTION PARAMETERS
305
ASSOCIATE COLORS WITH POWER LEVELS
310
BEGIN WITH INITIAL PIXEL
315
USING THE PIXEL COORDINATES (X,Y), CALCULATE THE VALUES FOR THE POLYNOMIAL AND TRIGONOMETRIC FUNCTIONS AND COMBINE INTO F(x,y)
320
CALCULATE MOD(INT(A*F(X,y)+B),M) AND ASSIGN THE VALUE TO CURRENT PIXEL
325
FINISHED ?
YES
NO
330
STOP
335
MOVE TO THE NEXT PIXEL

FIG. 3

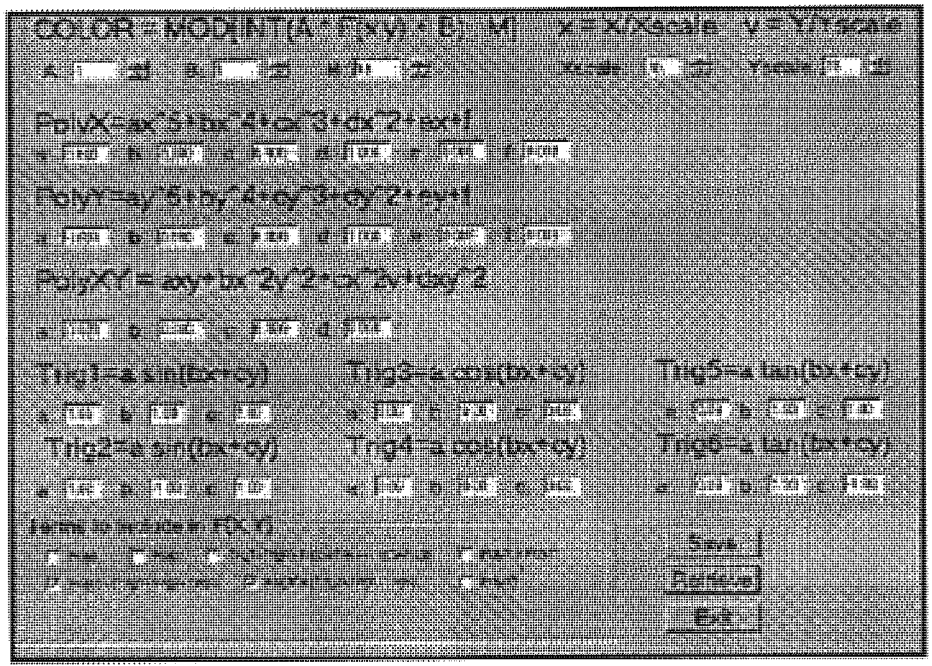

COLOR = MOD[INT(A * F(x,y) + B), M]
x = X/Xscale
y = Y/Yscale
Xscale
Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)
Save
Refresh
Exit

FIG. 4A

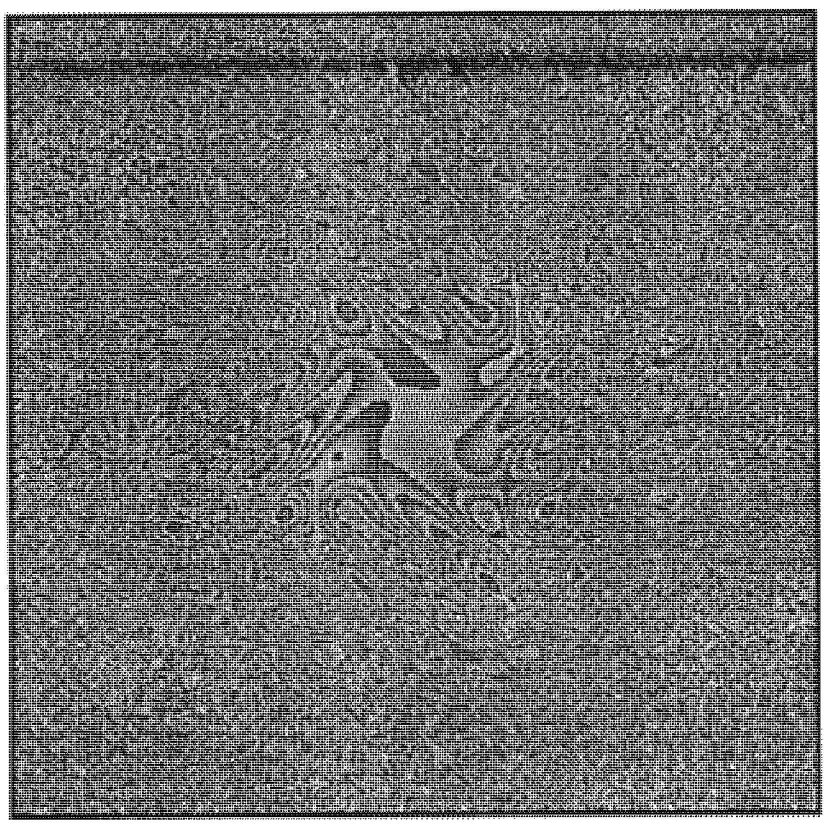


FIG. 4B

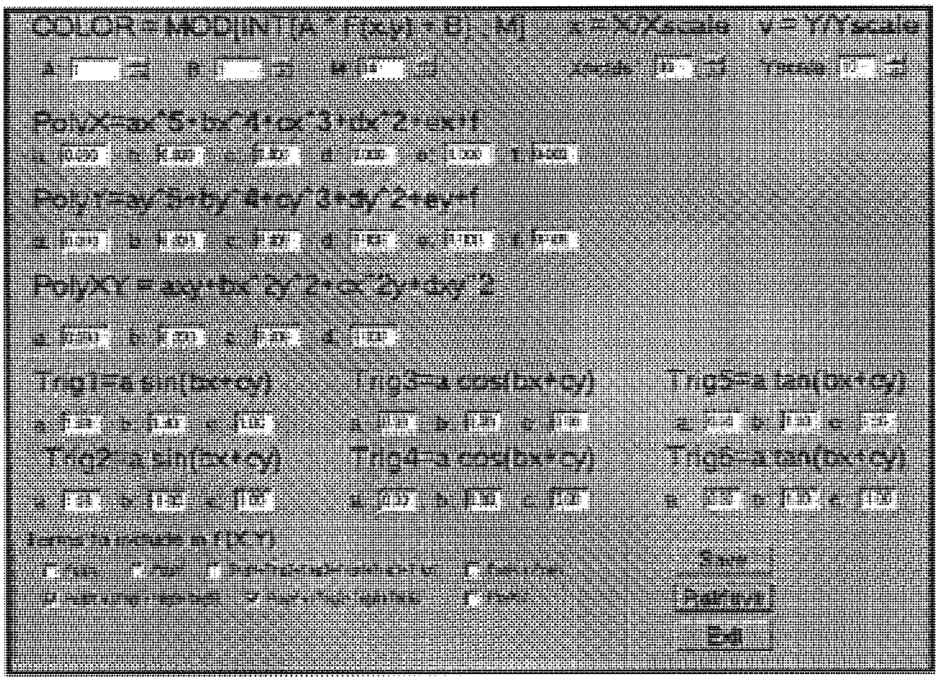

COLOR = MOD[INT(A * F(x,y) + B), M]
x = X/Xscale
y = Y/Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)

FIG. 5

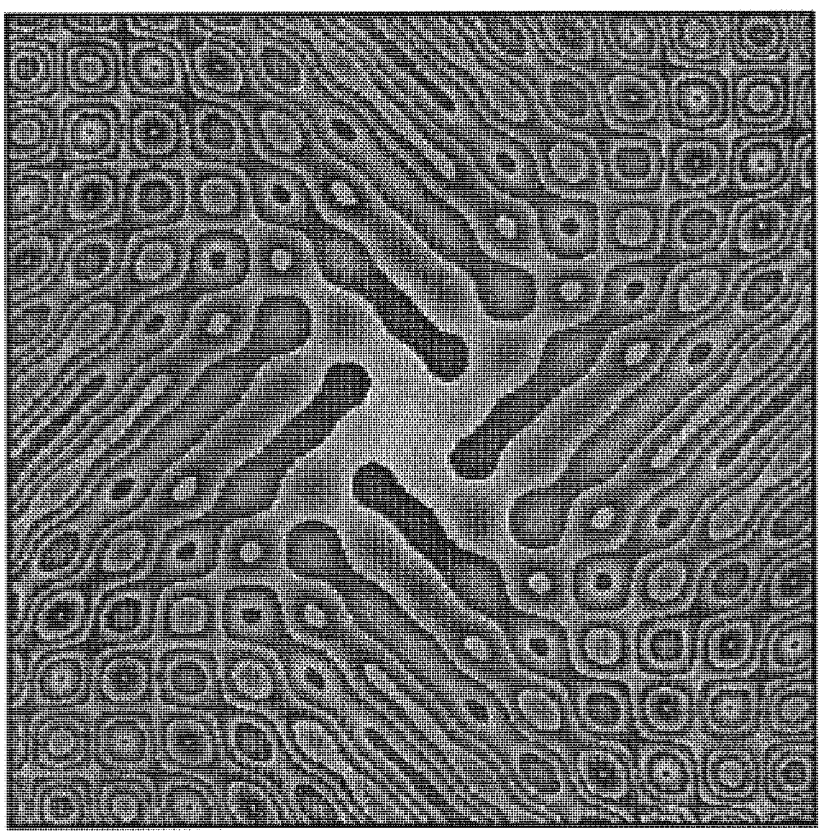


FIG. 6

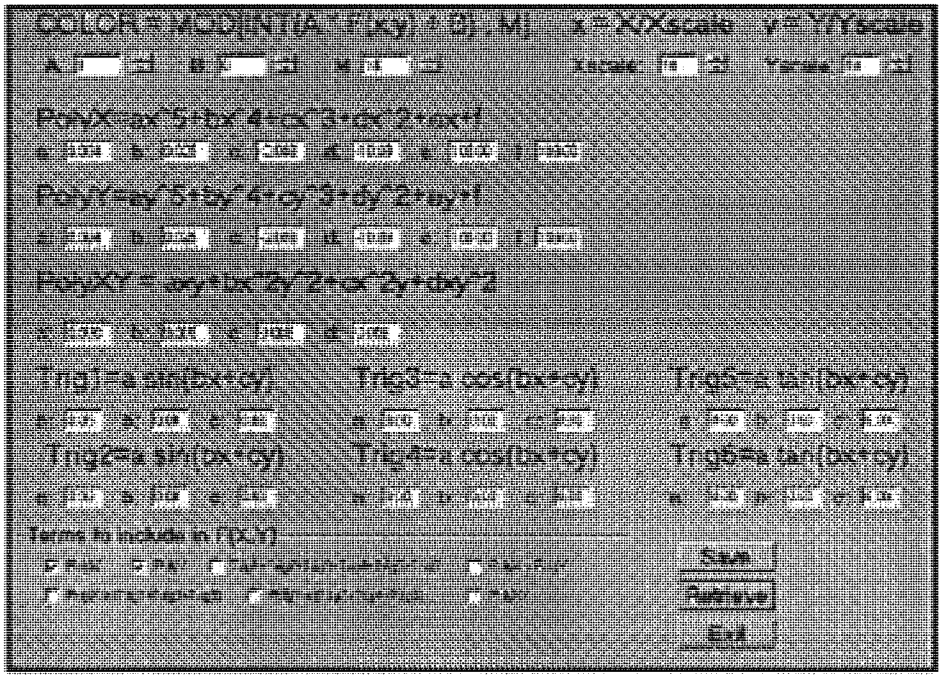

COLOR = MOD[INT(A * F(x,y) + B) , M]
x = X/Xscale
y = Y/Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)
Terms to include in F(X,Y)
Save
Retrieve
Exit

FIG. 7

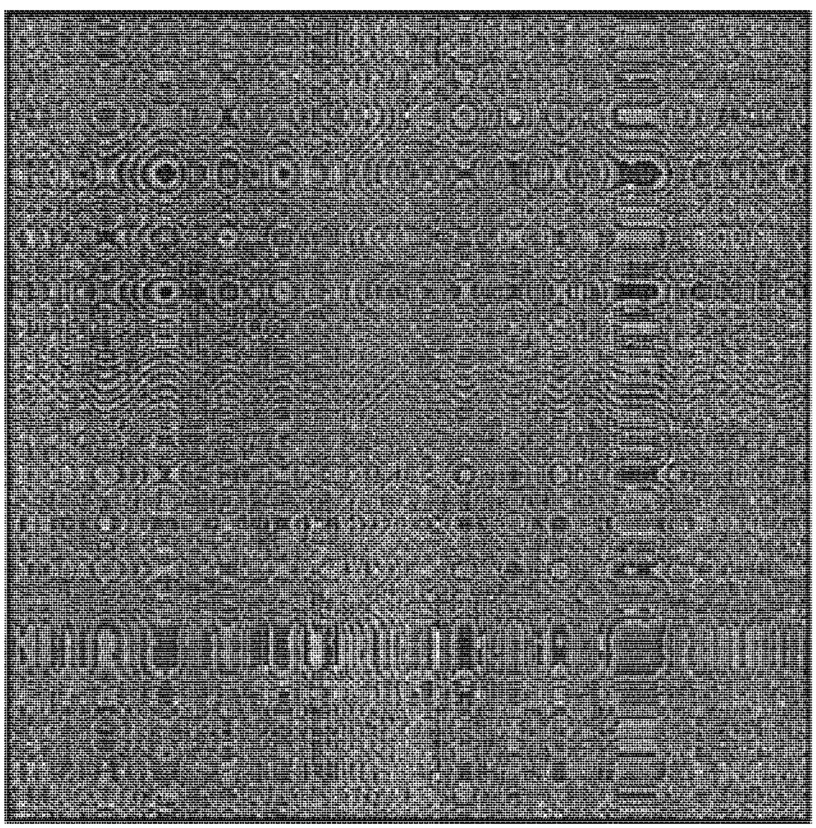


FIG. 8

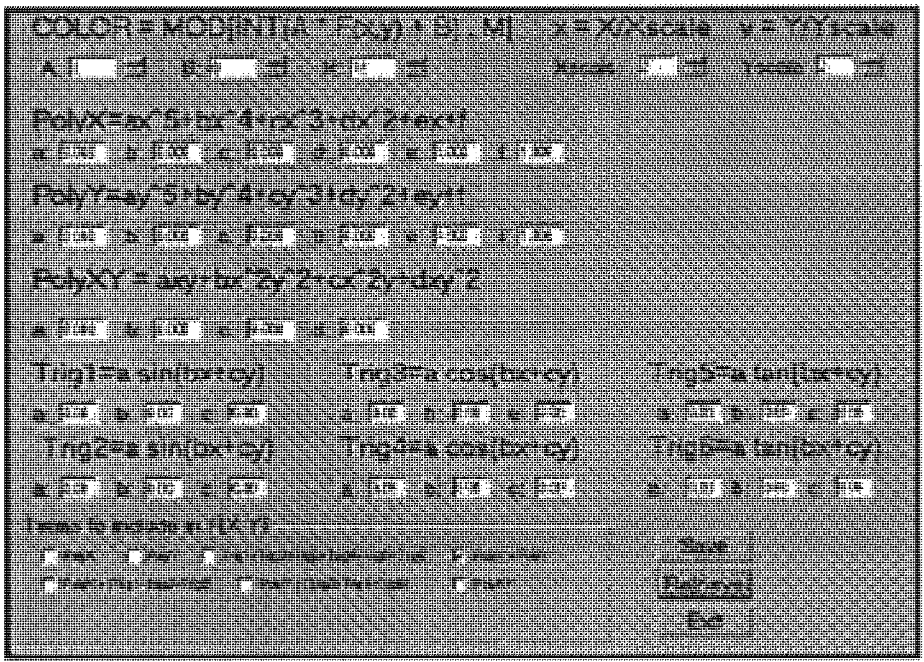

COLOR = MOD[INT(A * F(x,y) + B] , M]
x = X/Xscale
y = Y/Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)
Save
Retrieve
Exit

FIG. 9

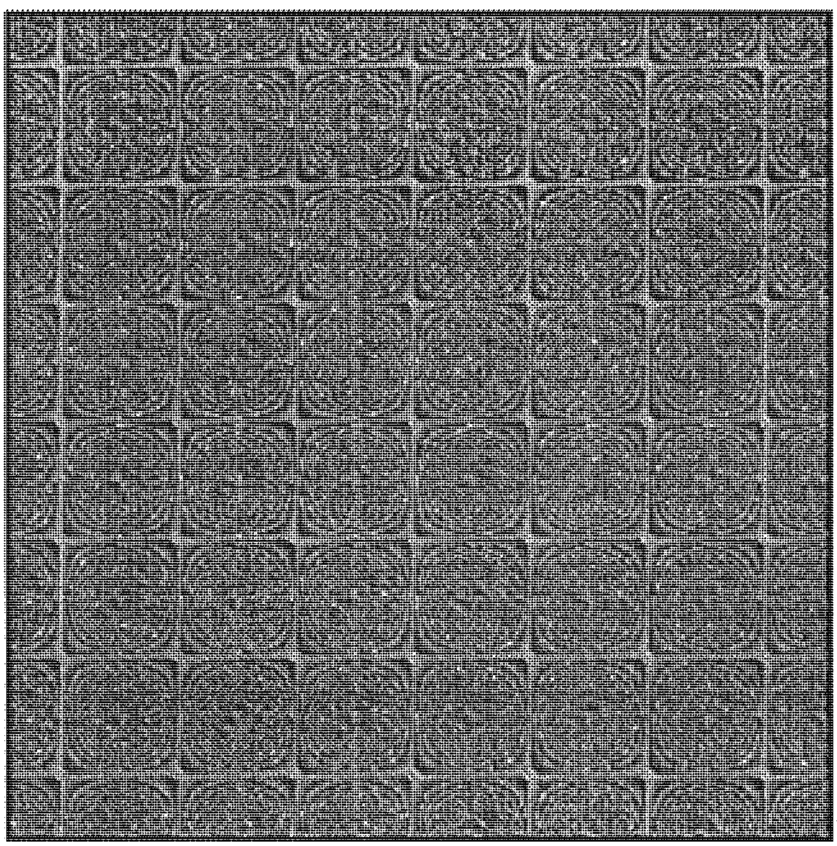


FIG. 10

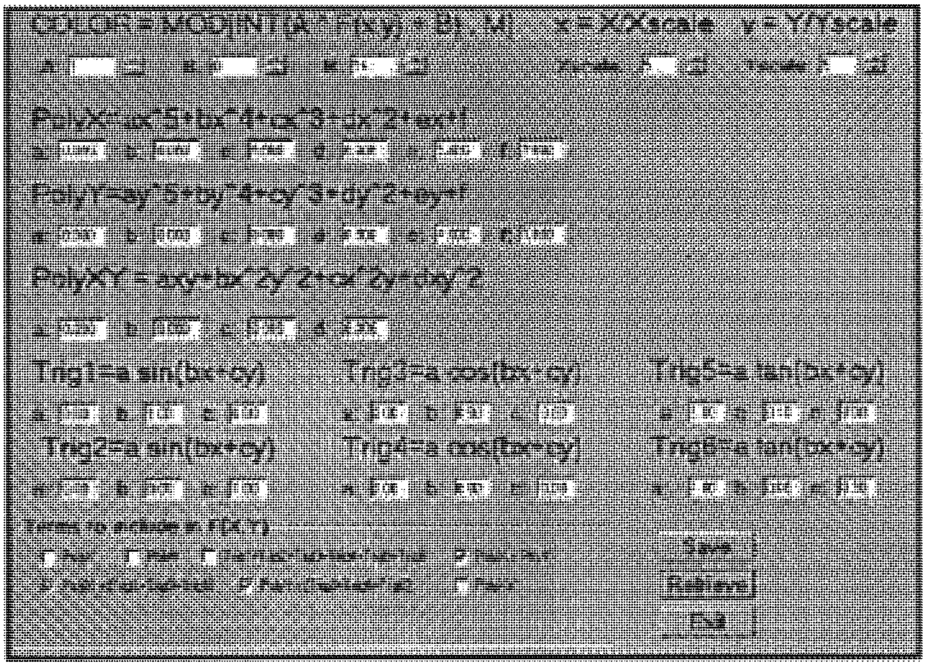

COLOR = MOD[INT(A * F(x,y) + B) , M]
x = X/Xscale
y = Y/Yscale
PolyX=ax^5+bx^4+cx^3+dx^2+ex+f
PolyY=ay^5+by^4+cy^3+dy^2+ey+f
PolyXY = axy+bx^2y^2+cx^2y+dxy^2
Trig1=a sin(bx+cy)
Trig3=a cos(bx+cy)
Trig5=a tan(bx+cy)
Trig2=a sin(bx+cy)
Trig4=a cos(bx+cy)
Trig6=a tan(bx+cy)
Save
Retrieve
Exit

FIG. 11

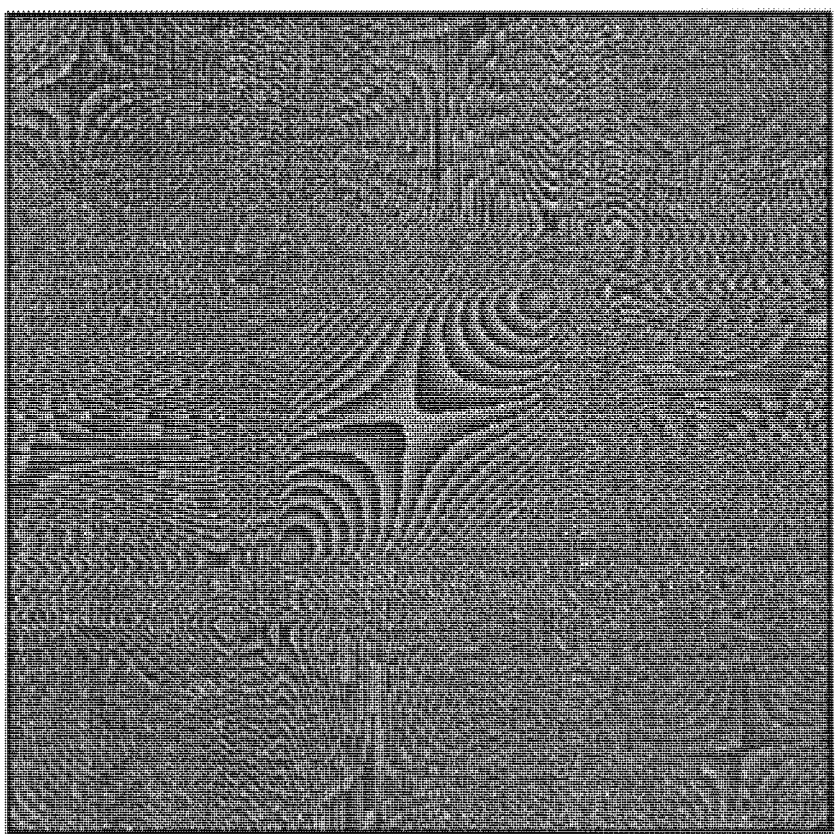


FIG. 12

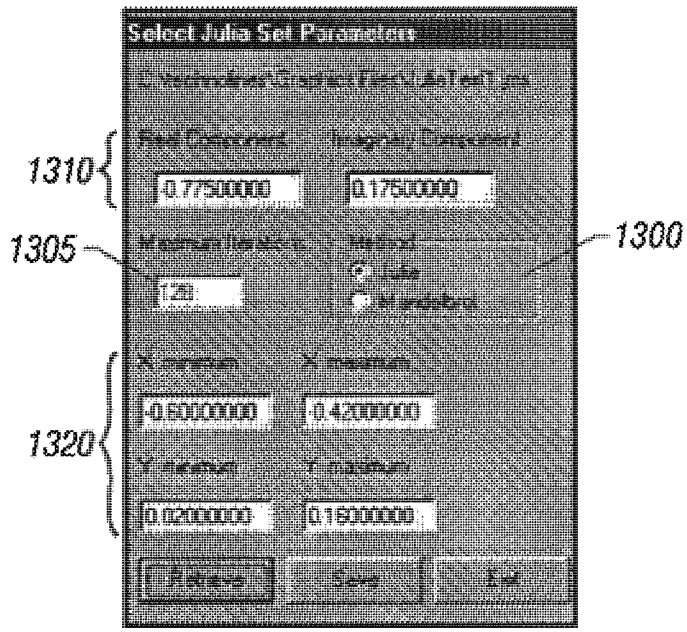

Select Julia Set Parameters
1310
-0.77500000
0.17500000
1305
128
1300
Julia
Mandelbrot
1320
-0.60000000
-0.42000000
0.02000000
0.16000000
Retrieve
Save
Exit

FIG. 13

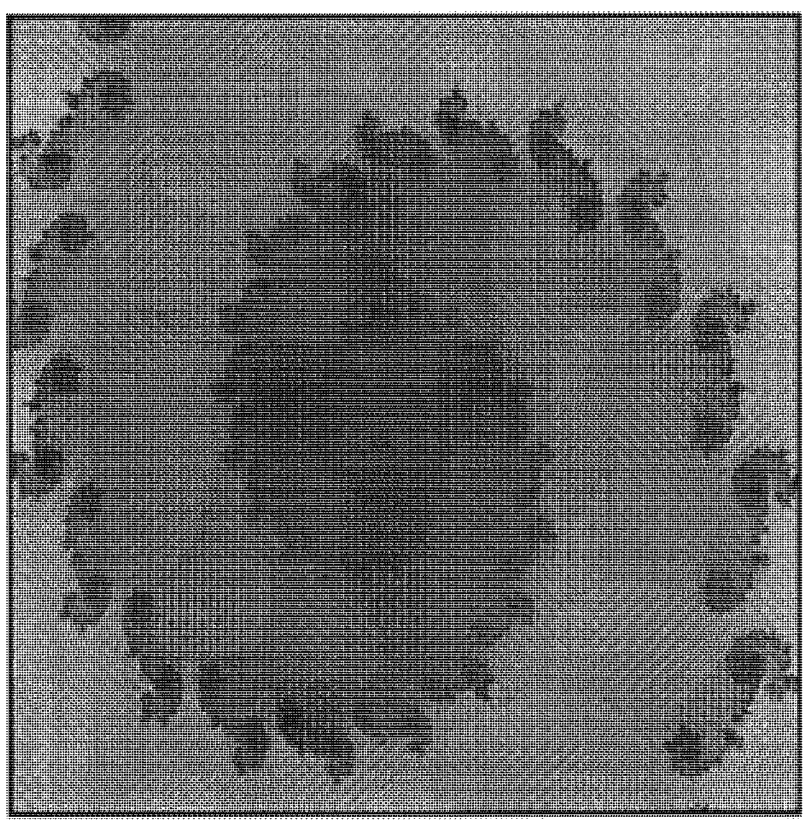


FIG. 14

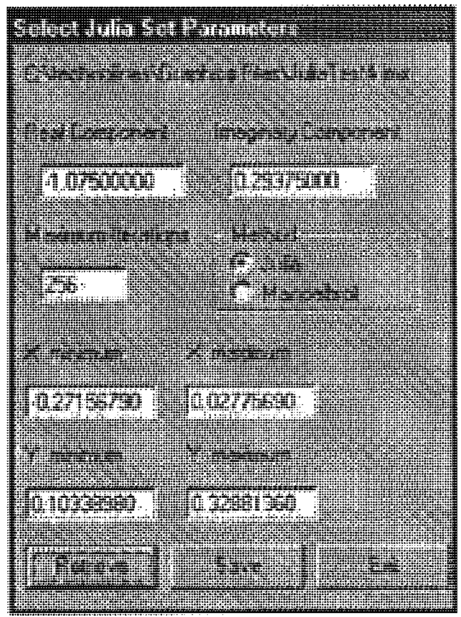

Select Julia Set Parameters
Real Component
Imaginary Component
256
Save

FIG. 15

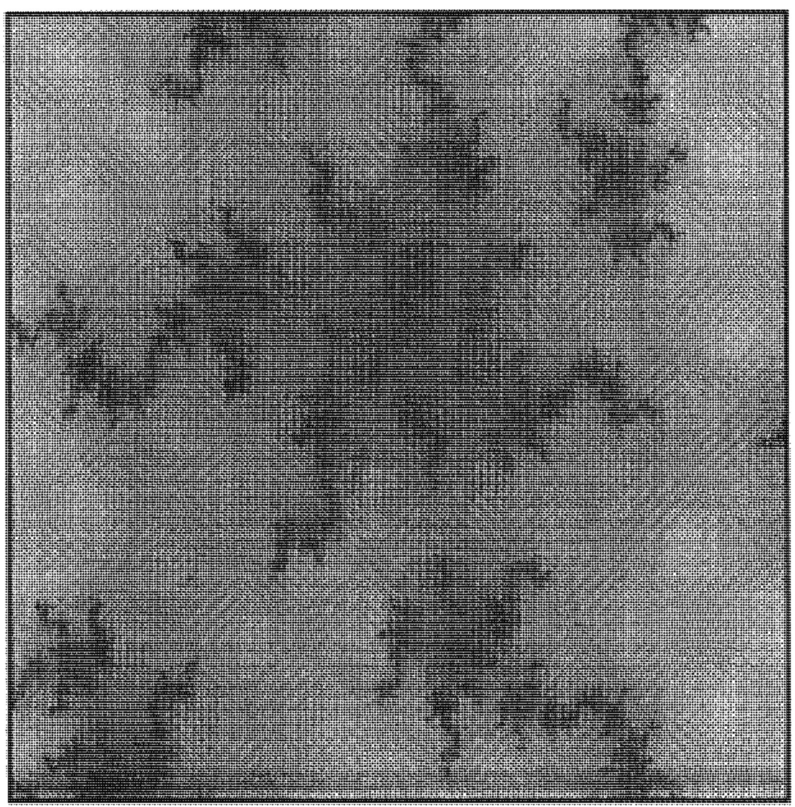


FIG. 16

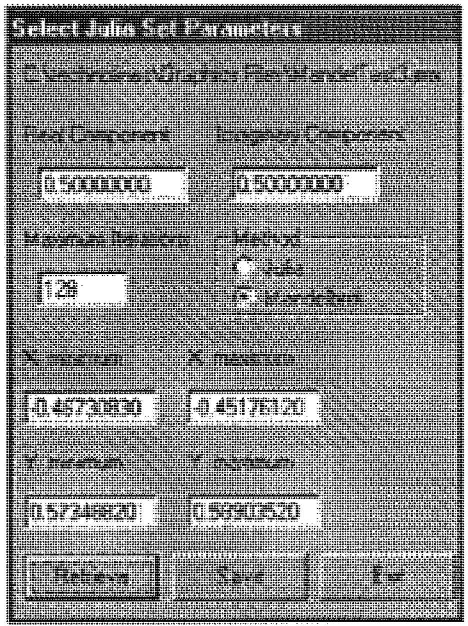

Select Julia Set Parameters
0.50000000
0.50000000
128
Method
-0.45176120
0.57248820

FIG. 17

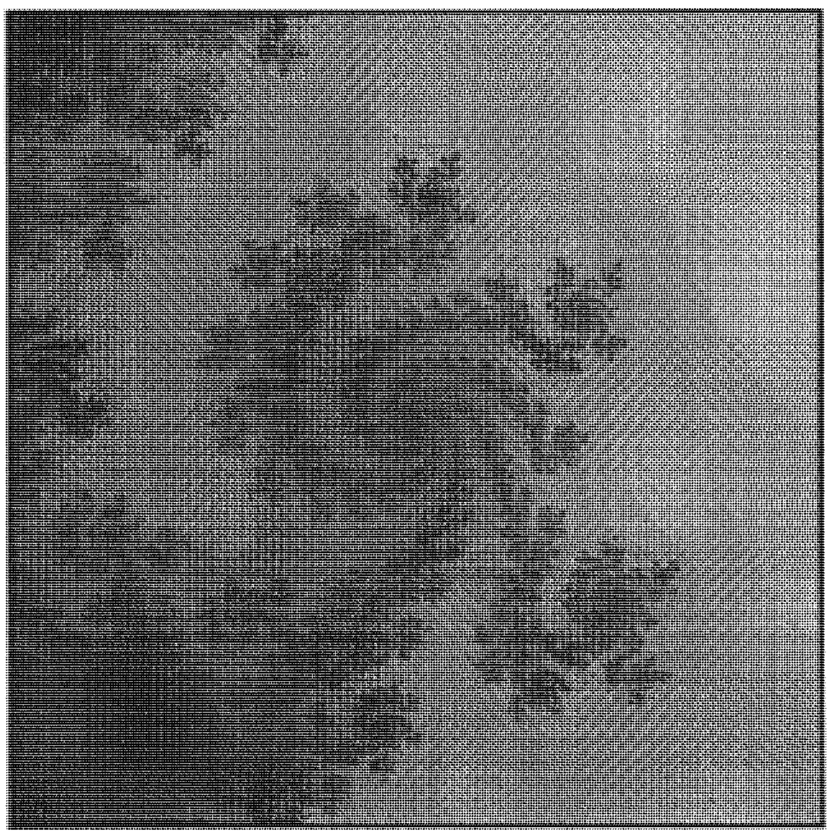


FIG. 18

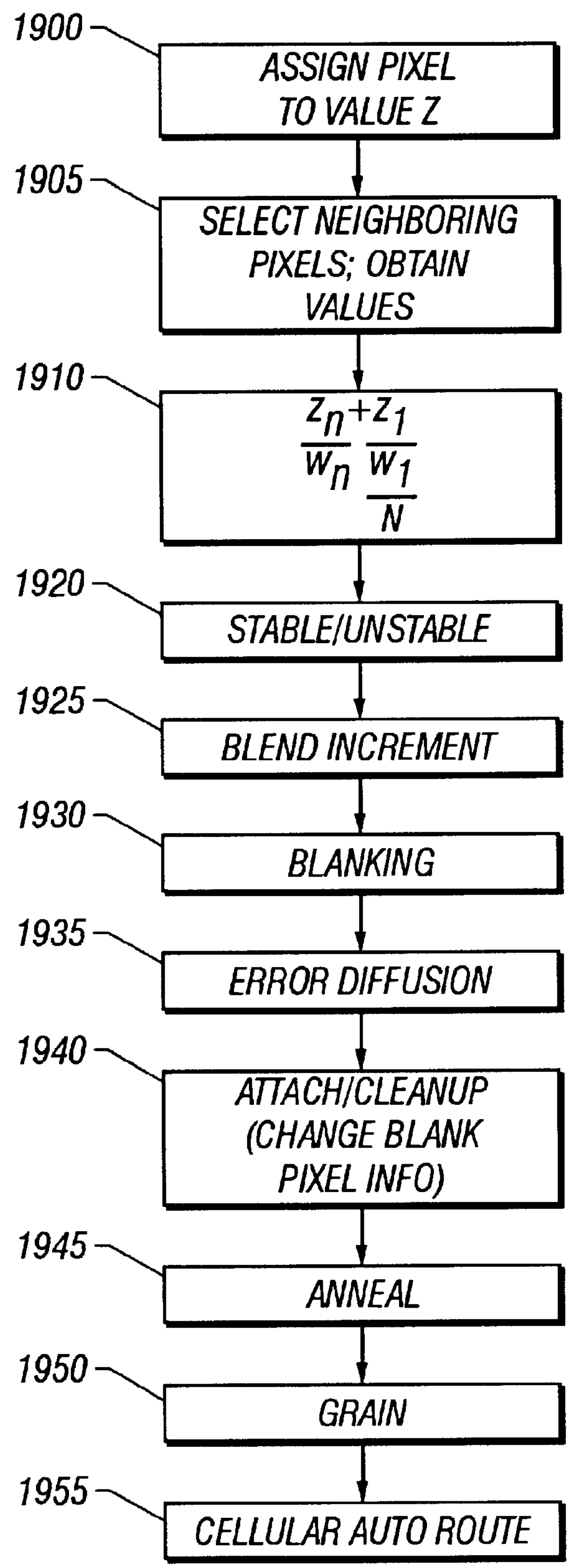

1900
ASSIGN PIXEL TO VALUE Z
1905
SELECT NEIGHBORING PIXELS; OBTAIN VALUES
1910
$\frac{\frac{z_n}{w_n}+\frac{z_1}{w_1}}{N}$
1920
STABLE/UNSTABLE
1925
BLEND INCREMENT
1930
BLANKING
1935
ERROR DIFFUSION
1940
ATTACH/CLEANUP (CHANGE BLANK PIXEL INFO)
1945
ANNEAL
1950
GRAIN
1955
CELLULAR AUTO ROUTE

FIG. 19A

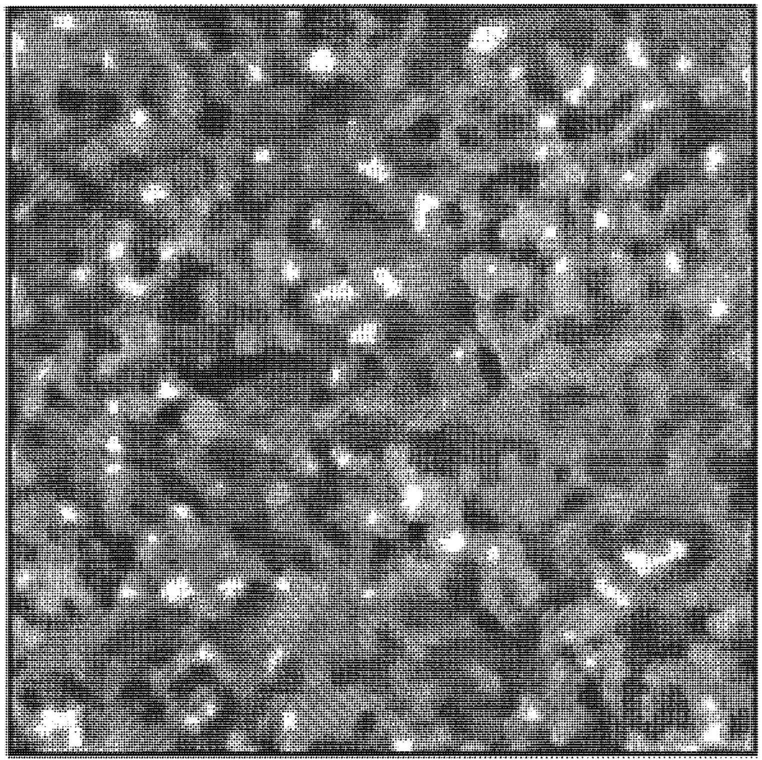


FIG. 19B

FIG. 20

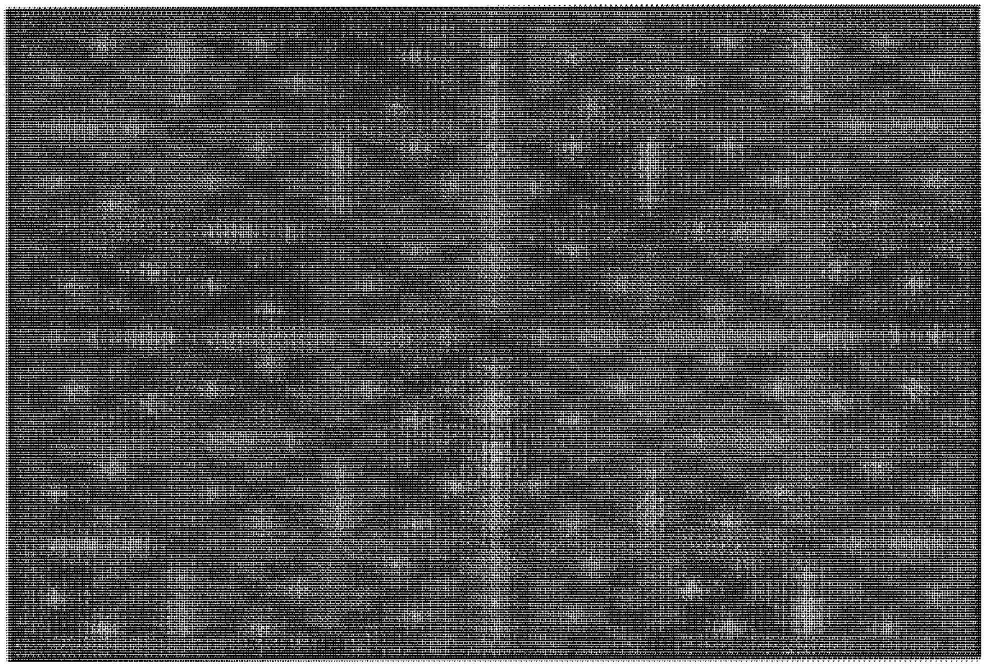


FIG. 21

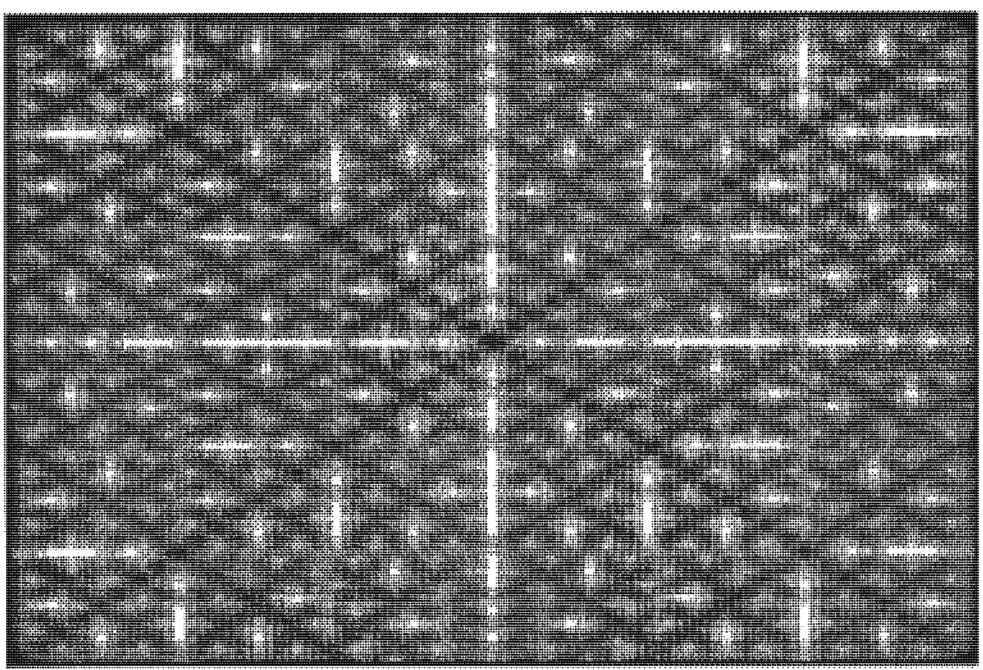


FIG. 22

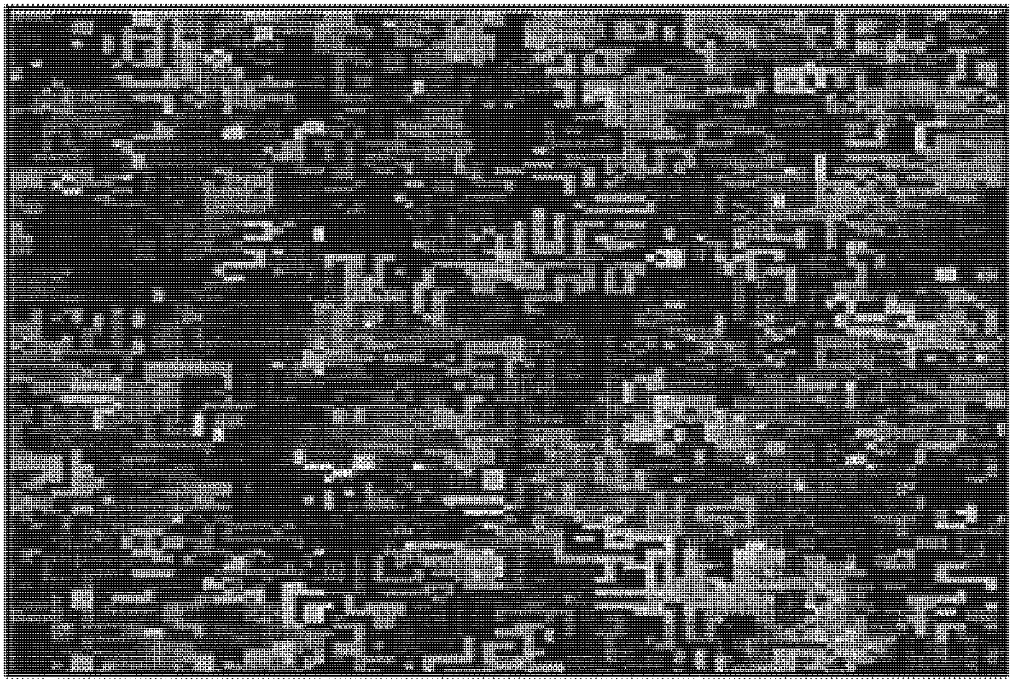


FIG. 23

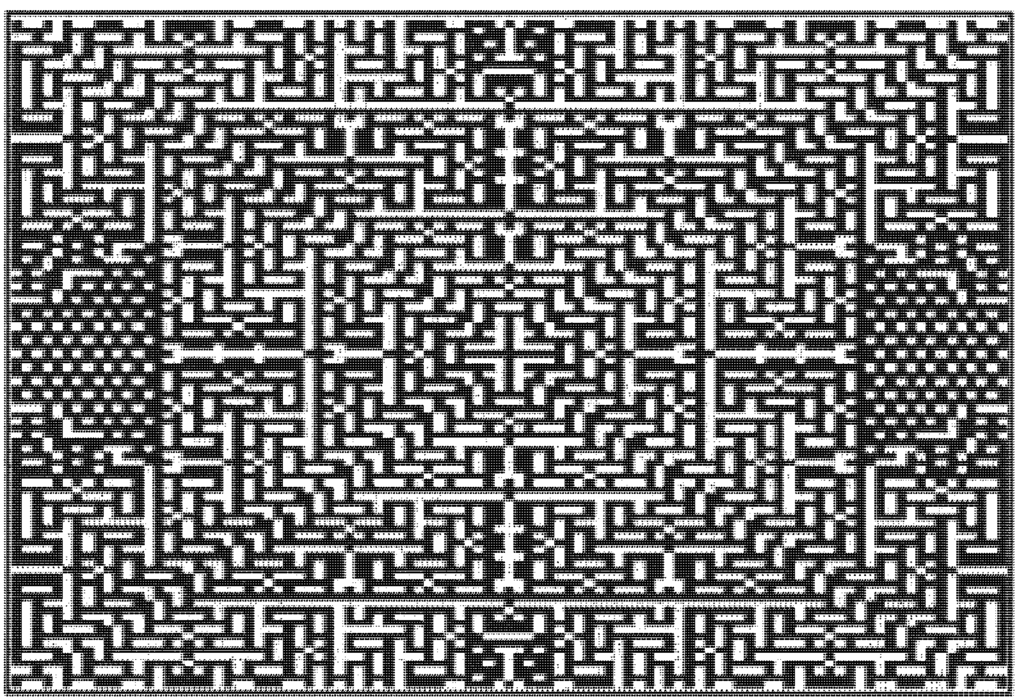


FIG. 24

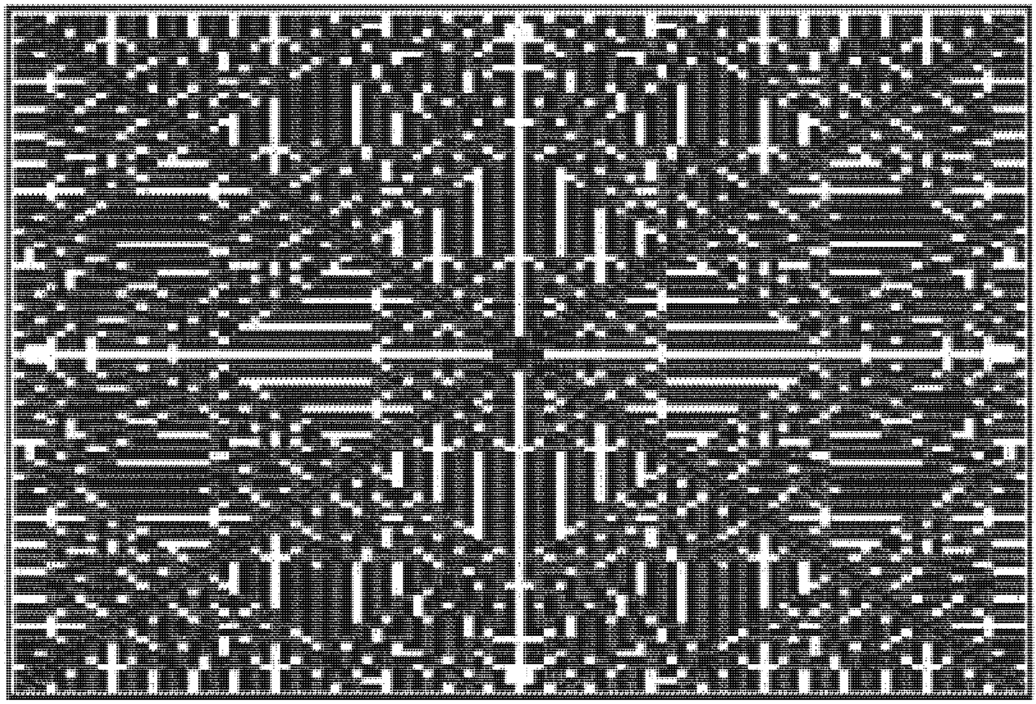


FIG. 25

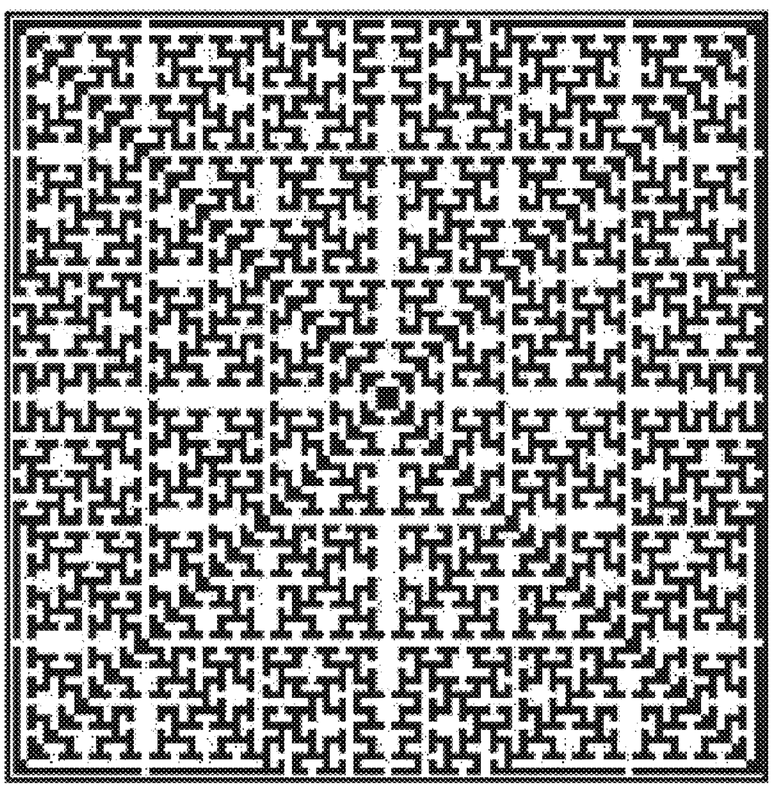


FIG. 26

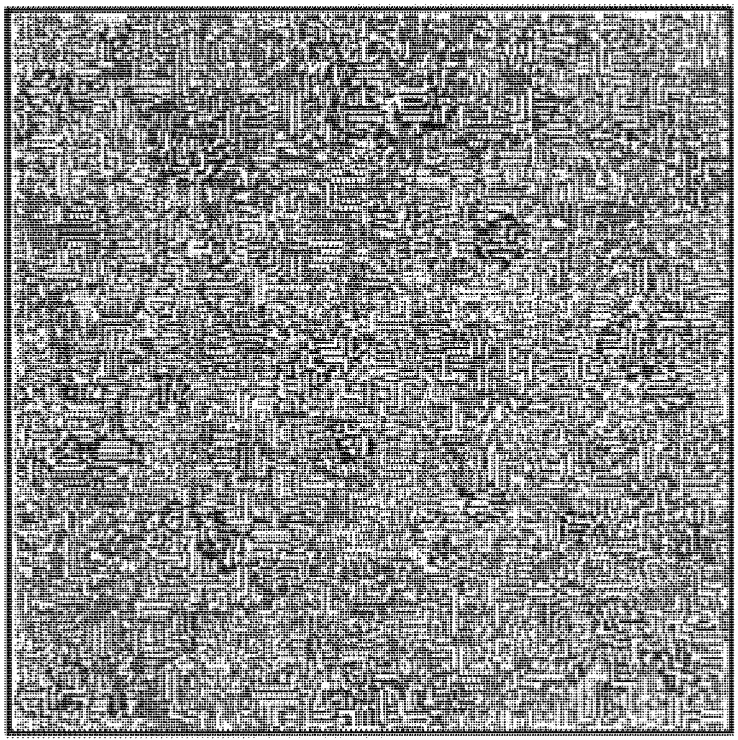


FIG. 27

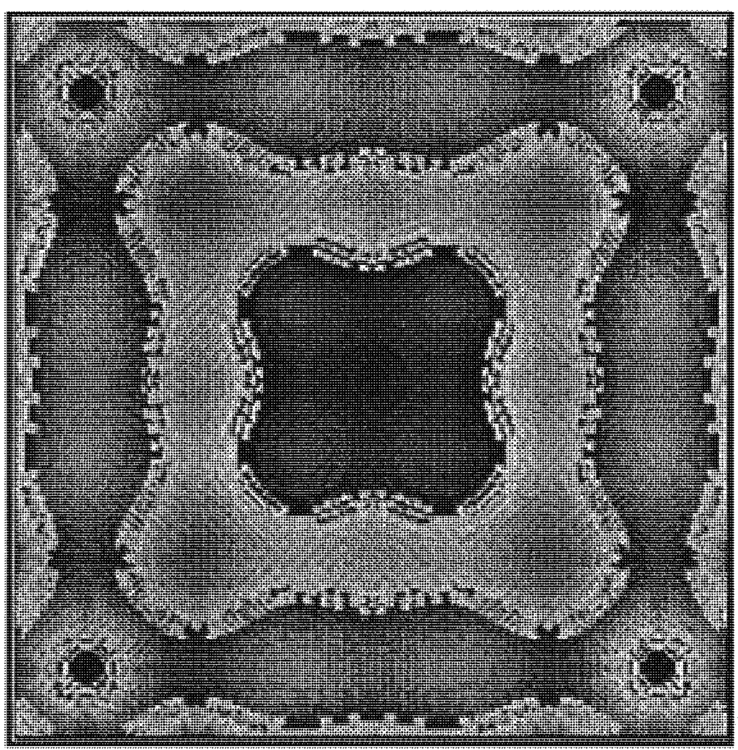


FIG. 28

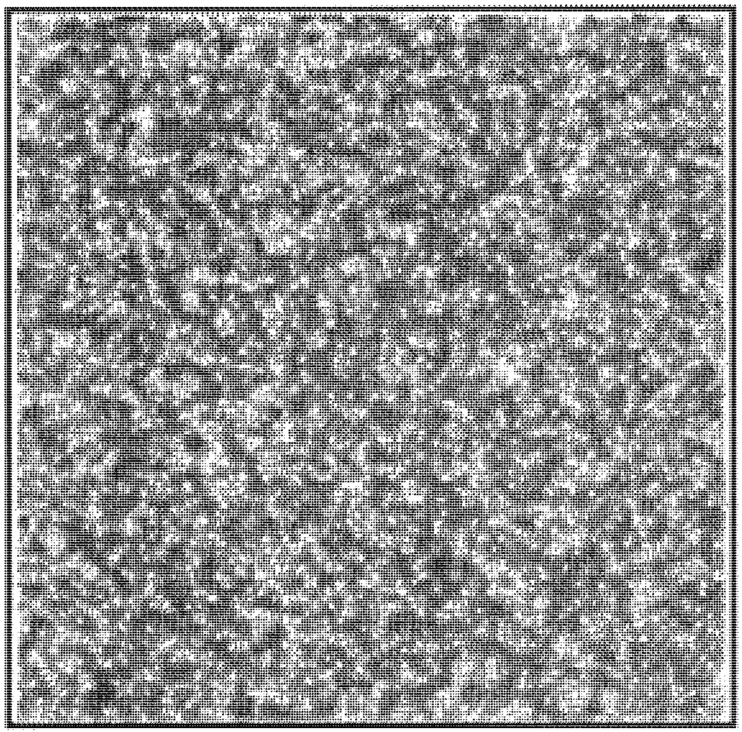


FIG. 29

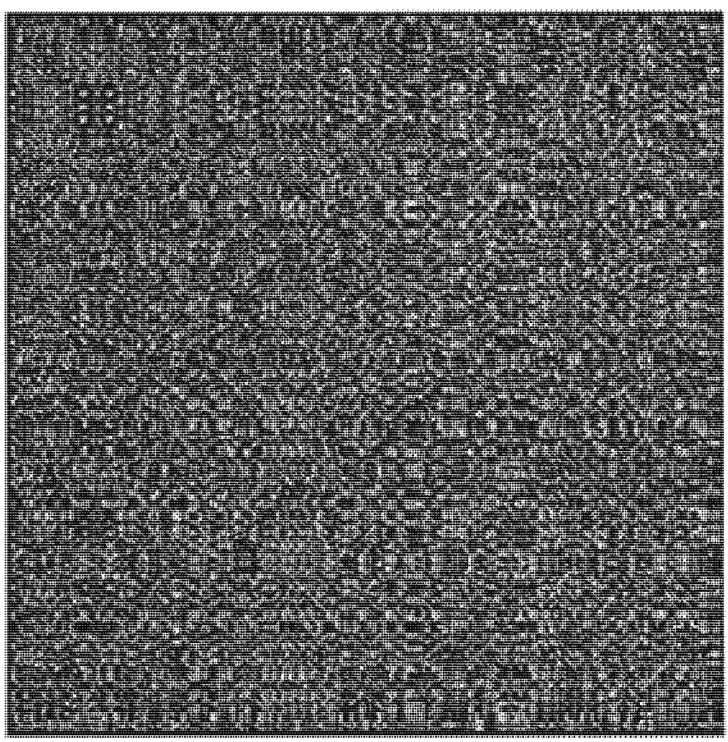


FIG. 30

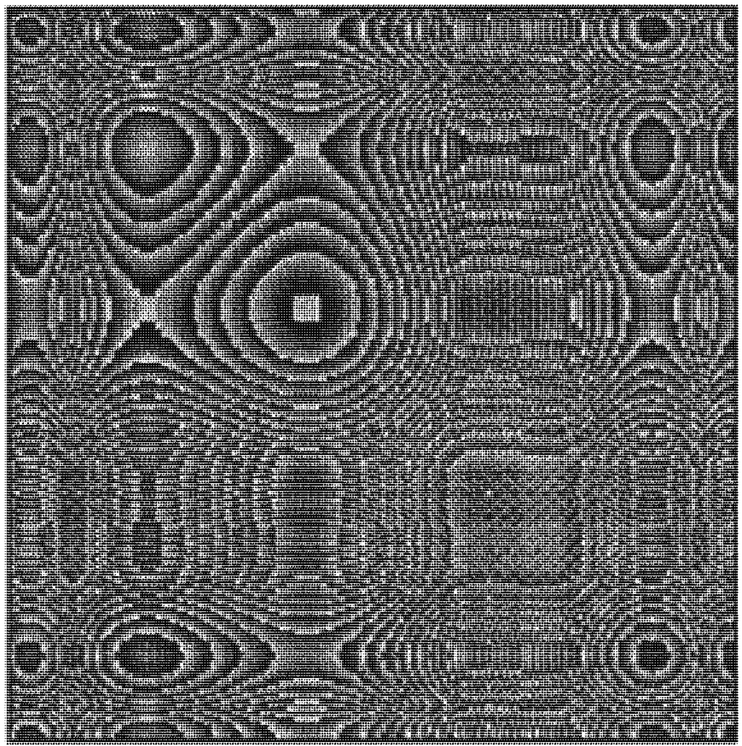


FIG. 31

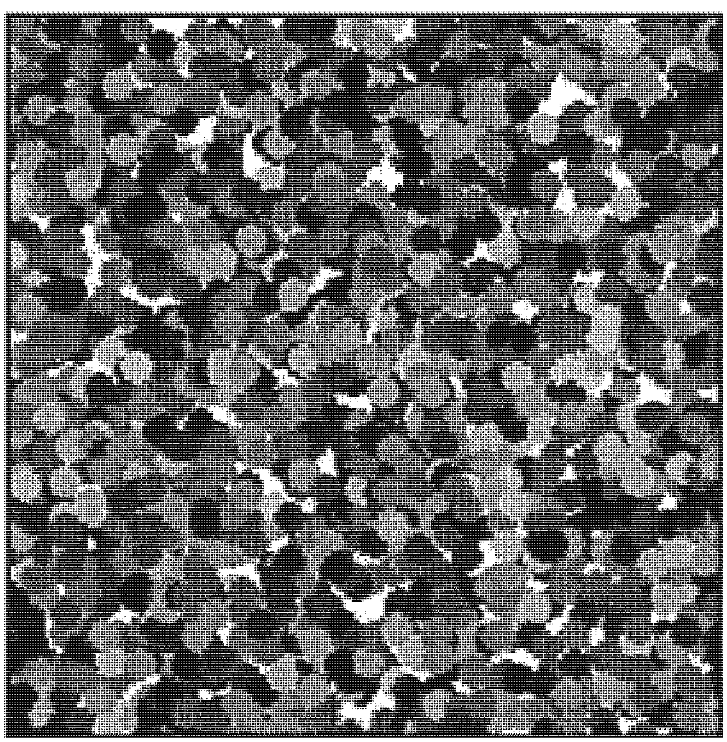


FIG. 32

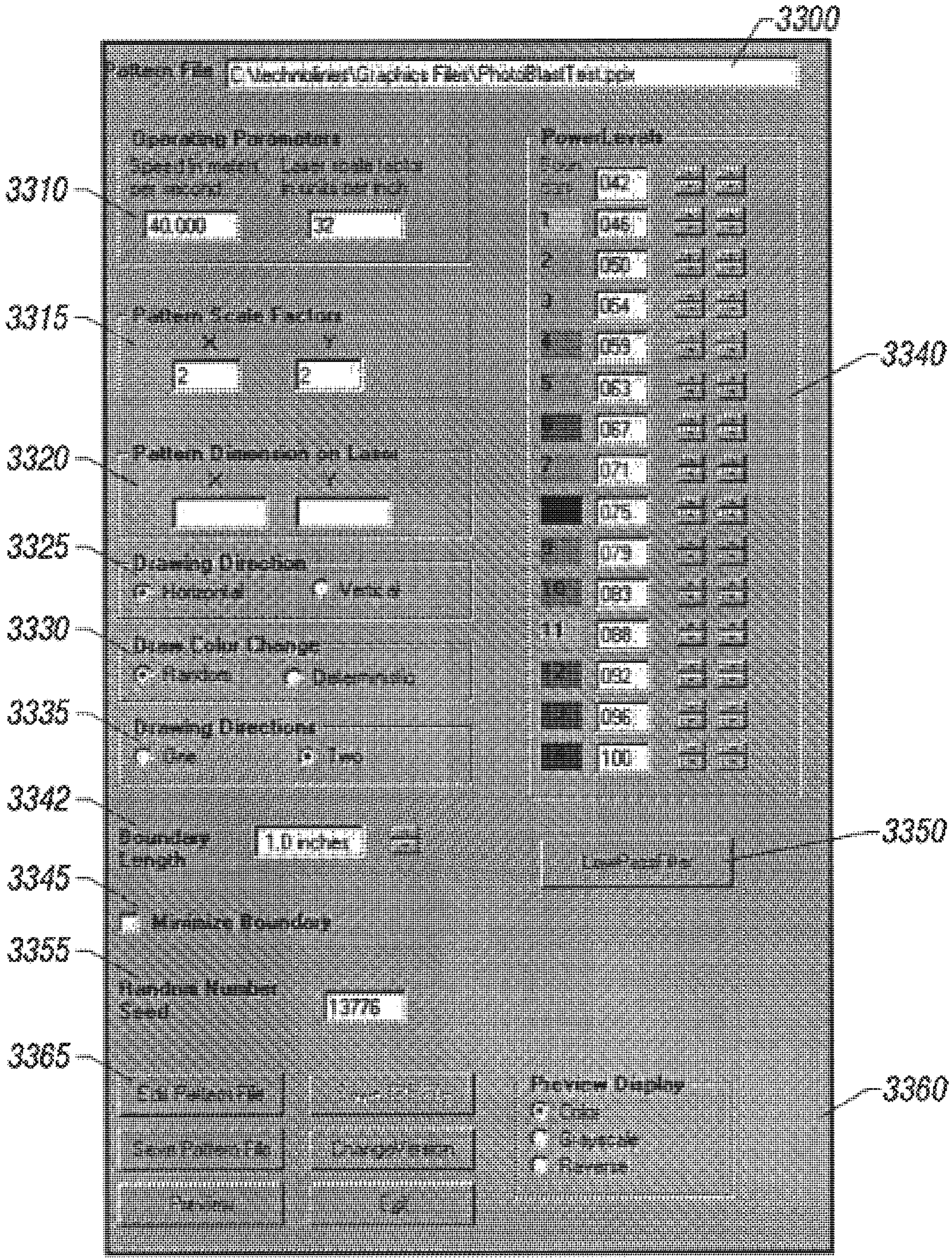

3300
Pattern File
3310
Operating Parameters
40,000
32
3315
Pattern Scale Factors
X
Y
2
2
3320
Pattern Dimension on Laser
X
Y
3325
Drawing Direction
Horizontal
Vertical
3330
Draw Color Change
Random
3335
Drawing Directions
One
Two
3342
Boundary Length
1.0 inches
3345
Minimize Boundary
3355
Random Number Seed
13776
3365
Edit Pattern File
Save Pattern File
Preview
Exit
Power Levels
042
046
050
054
059
063
067
071
075
079
083
088
092
096
100
3340
3350
Preview Display
Color
Greyscale
Reverse
3360

FIG. 33

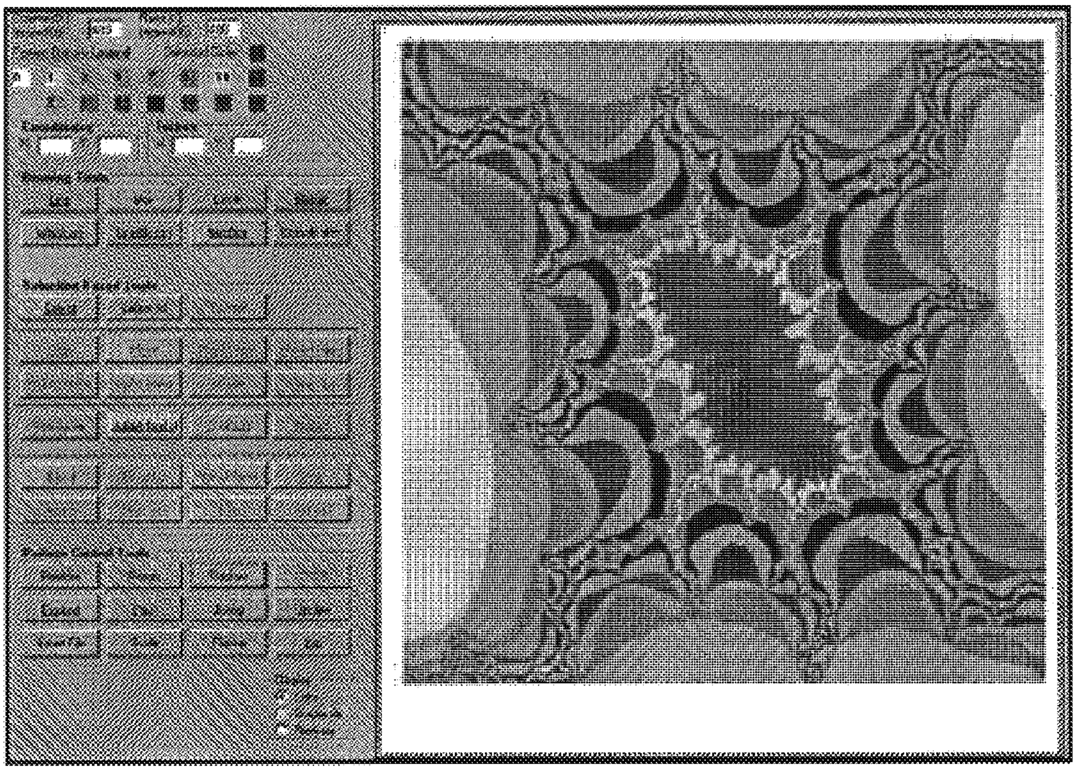


FIG. 34

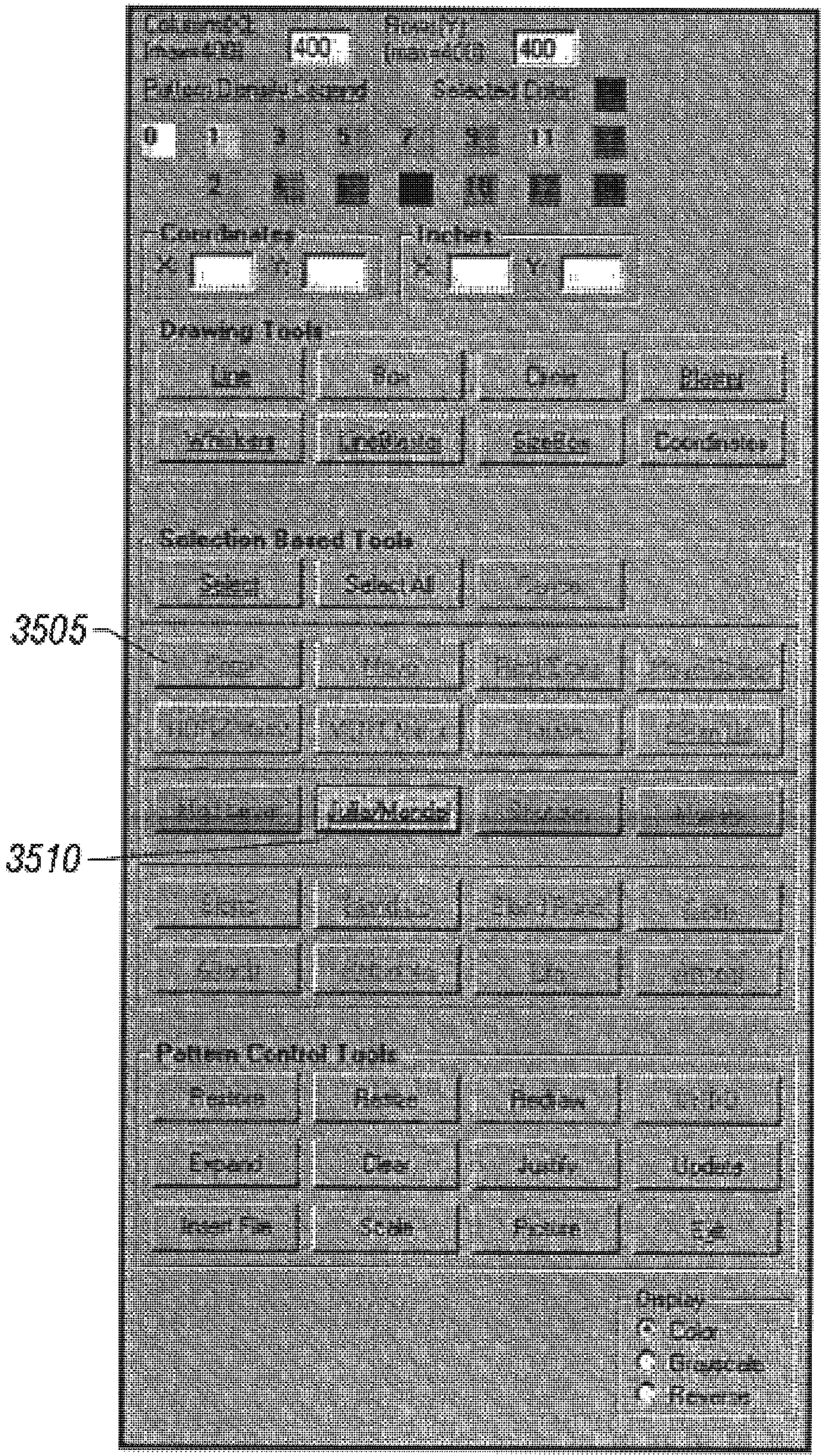

400
400
Selected Color
0
1
3
5
7
11
2
Coordinates
Inches
Drawing Tools
Line
Box
Clear
Coordinates
Selection Based Tools
Select
Select All
Pattern Control Tools
Restore
Redraw
Expand
Clear
Justify
Update
Insert File
Scale
Picture
Display
Color
Grayscale
Reverse
3505
3510

FIG. 35

LASER PROCESSING OF MATERIALS USING MATHEMATICAL TOOLS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the U.S. Provisional Application No. 60/169,096, filed on Dec. 6, 1999.

BACKGROUND

Garments are conventionally processed to obtain specified looks on the garments. Denim materials, such as denim jeans, are often processed.

Denim is often processed using stone washing, enzyme washing, sandblasting, and other techniques. More modern techniques may include embroidery, and other pattern production.

U.S. Pat. Nos. 5,916,461, 5,9900,444, and others have described using a laser to simulate the looks that are conventionally produced by sandblasting and other conventional techniques. This has included simulating looks and patterns produced by local abrasion, a global abrasion, whiskers, and imprints. The patents have also described scribing decorative graphics obtained from clipart.

U.S. Pat. Nos. 5,916,461 and 6,002,099 describe using random processes to place various geometric objects into a drawing field. The user can control the drawing field to provide desired looks on the denim materials.

SUMMARY

The present application teaches additional tools and techniques intended for controlling a laser to produce an output beam that changes the look of a specified garment or material in a new way. One specific technique uses a mathematically-based process to automatically generate a pattern, or a portion of a pattern, which can be produced on either part or all of a specified garment.

Another aspect defines the specified mathematical techniques, which may include fractal techniques, modular level set techniques, cellular automata techniques, and specified iterative techniques.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will now be described in detail with reference to the accompanying drawings, wherein:

FIG. **1** shows a block diagram of the basic system of the present invention including the processor, and the marking device being a laser;

FIG. **2**A shows a user interface for a modular level set, and FIG. **2**B shows an actual pattern obtained from that specific values in that modular level set;

FIG. **3** shows a flowchart of operation for the modular level set function;

FIGS. **4**A and **4**B; **5**/**6**; **7**/**8**; **9**/**10**; **11**/**12** show additional sets of specified values and effects obtained from those specified values;

FIG. **13** shows a user interface for selection of fractal parameters, and FIG. **14** shows a fractal design obtained from those actual parameters;

FIGS. **15**/**16**; **17**/**18** show additional fractal parameters;

FIG. **19** shows a flowchart of tool operations for the images;

FIGS. **19**B, **20**–**32** shows specific patterns which are obtained from these values;

FIG. **33** shows a user interface for associating colors with power levels and setting values of a marking units such as a laser;

FIGS. **34** and **35** shows the overall drawing tool for the system.

DETAILED DESCRIPTION

The basic system using the present application is shown in FIG. **1**. A high-power laser **100** produces a laser output **102** which is directed at a working surface **110**. A garment **115** is shown placed on the working surface at a location of the laser **102**. The laser **100** is preferably a high-power laser, e.g. one which has a power output greater than 200 watts, and configured in a way which provides the capability of changing its energy density per unit time at any time, e.g., including during a specified scan line of the laser. A material delivery system, shown generically as **120** obtains textile materials to be processed, and places the materials in the location shown in the drawing, to be processed by the laser.

While the marking device is shown in this figure as being a laser, it should be understood that other marking device can be used as described herein.

The materials **115** may include bulk fabric or pre-made garments. The fabric forming these garments can be of any type, although special advantages may be obtained when the fabric is denim. The material delivery system and the laser are each controlled by a central processing computer shown as **130**. The computer **130** can be multiple separate computers or can be a single computer. The computer **130** also runs a software program shown as **140** which produces output codes that control the laser operation. A user interface including a display **150** and control **160** enables the user to enter commands on the control **160** which are displayed on the display **150**.

In operation, the control software **140** carries out a number of different operations described herein. First, the software **140** allows selecting various effects to be written on material **115**. These effects can be any of the effects described in our previous patents, or alternatively can be the specified mathematical effects which are described herein. The software **140** also stores a database of effect codes.

The effect codes show the effect of the laser on the actual microstructure of the fabric. Effects of various laser powers on specified materials may be included within the effect codes. Each effect code may represent some aspect of the way that a specified writing will affect a specified material. The software can use the effect codes to simulate how the fabric will look when the pattern is applied by the laser to the fabric. One way in which this can be done is to simply define each effect as having a specified output look on the material. Then, the effects are viewed on the screen **150**, based on each output look. In addition, the effect codes may represent different effects that will be caused based on the weave of the material, e.g., the direction of the denim weaves.

Therefore, another operation of the software allows the user to test the image that is created from these techniques, without actually using the laser system.

The user can interact with the effect selection by entering parameter values, modifying looks and producing a final pattern to be written on to the material.

The selection of effect uses a tool set which is described in further detail herein. The tool set includes:

1) a plurality of pattern generation tools. The pattern generation tools are based on modular level sets of mathematical functions.

2) a special set of a pattern generation tools that is based on fractal mathematics.

3) a set of blending and/or smoothing tools;

4) a set of graining and or annealing tools;

5) a set of pattern generation and manipulation tools based on concepts from cellular automata.

A first tool, based on modular level sets, is shown in the user interface of FIG. **2**A and the flowchart of FIG. **3**. FIG. **2**A shows the different kinds of mathematical elements that can be used. Any or all of these mathematical elements can be used within a single image.

At **300**, the user first sets scale factors and function parameters on the user interface of FIG. **3**. The first, pattern generation tools shown as elements **200**, may operate on a pattern that is formed on a pixel level. Each pixel is first assigned x,y coordinates (x,y). A "pixel" can be any size picture element. For example, a pixel can be larger than the corresponding pixel element unit that is displayed on a display screen. A pixel's size may be set to any size that produces the desired effect on the material being processed, and can be from um size, to inches.

A parameterized function F(x,y) may be selected. The parameterized function may be selected from known mathematical functions. Example mathematical functions may include polynomials, trigonometric functions, such as sine, cosine, tangent, inverse trigonometric functions such as arc sine, arc cosine, arc tangent, exponential functions, logarimithic functions, hyperbolic functions such as hyperbolic sine, inverse hyperbolic functions, Fourier transforms, Bessel functions, factorial, Root functions and others.

Different aspects of the software **140** are described herein. A first aspect relates to the specific pattern generation tools.

At **305**, an initial definition is made that associates "colors" with specific power levels. Each "color" can be a conventional color, or a gray scale, or any other indicia that can be viewed on a screen or user interface. Each color is associated with a specified amount of output energy from the laser. The amount of output energy can be measured as energy density per unit time, amount of energy output, or any other level of energy output. FIG. **33** shows the basic user interface which can be used to associate the amount of output energy with the colors that are used.

Each of the colors in the pattern becomes a variable value. Each specific pixel at (x, y) is associated with a variable color. The set of pixels form the image. Again, the pixels do not need to be of any specified size, they can be arbitrarily small or arbitrarily large. The pixels of the image can be changed, either one by one, or a group at a time. According to the present system, the change is calculated according to a specified function.

Therefore, in the flowchart of FIG. **3**, the system begins with an initial pixel at **310**.

At **315**, using the pixel coordinates x,y the values for the modular level sets are calculated. This is combined into F(x,y). At **320**, the remaining parts of the function are calculated. If the operation is completed at **325**, the system stops at **330**. If not, then the system moves to the next pixel at **335**.

Once the entire image is obtained, the values are converted into a form that can be used by the laser, and mapped to laser scan lines.

The preferred technique described herein forms the effect on the material using a laser to change the look of the material. However, this same technique can also be used to form a pattern which changes the look of the material using a different technique, such as by silk screening, printing, painting, or any other technique.

FIG. **2**A shows a first user interface screen in which the mathematical function used to select the "colors" includes modular value sets, or more specifically, functions of the form $ax^n+bx^{n-1}+\ldots$ either by themselves, or in combination with other parts such as integer and modulus. The user interface allows entering values for the modular sets. A first field **200** determines the color at the pixel as color=MOD [INT(A*(F(x,y)+B), M], (**320**, in FIG. **3**) where MOD is the modulus or "remainder" function, INT is the integer or "rounding" function, and A and B are user parameters.

Each of the user parameters A, B and M can be changed by the user.

The function F(x,y) can also be changed to any of the functions shown as **210**, **220**, **230** or others including the specific functions described herein.

The different functions define how the color for each image portion, e.g., each pixel, is calculated. Each color includes a polynomial function as in **210**, where

Poly $x=ax^5+bx^4+cx^3+dx^2+ex+f$.

Another specific function is shown in **220**, where

Poly $y=ay^5+by^4+cy^3+dy^2+ey+f$.

The function can be made more complex in **230**, using the function

Poly $x,y=axy+bx^2y^2+cx^2y+dxy^2$.

240 shows a set of trigonometric functions. These functions include, as described above, sines, cosines and tangents. The specific trigonometric functions are shown as:

Trig1=a sin(bx+cy)

Where each of a, b and c are separately controllable,

Trig3=a cos(bx+cy)

And

Trig5=a tan (bx+cy)

A bottom portion **250** allows the user to select which of the terms to include in the F(x,y). If any of the terms become inconsistent with one another, then the user interface may take some action to prevent these terms from being used, e.g., may shade certain items once others are selected.

The actual information in FIG. **2**A has selected field **210**; poly x, with a=1; b=0; M=14, with b=0.06, c=0.02, d=−6.0, e=−20 and f=8.

Poly y is also selected with b=0.06; c=0.2; d=−6, e=−20 and f=8. None of the other terms are included in F(X, Y), as shown in the selection area **250**.

The actual results of these specific parameters is shown in FIG. **2**B. This produces a complicated pattern. The pattern can also be scaled using the X scale **260**, and y scale **270** controls.

The pattern in FIG. **2**B shows a complex series of concentric circles arranged in whorls like a fingerprint. Other patterns are also obtained.

The parameters shown in FIG. **4**A result in the pattern shown in FIG. **4**B. In this parameter set, the values form a central enlarged portion, with the other portions having other characteristics. The parameters shown in FIG. **5** results in the pattern shown in FIG. **6** in which a plurality of wormlike structures are formed, each with central round portions. FIGS. **7** and **8** show additional features. FIGS. **9** and **10** show any repeating feature set in which each feature is a substantial unit which includes concentric portions therein. The concentric portions are virtually divided into different quadrants. FIGS. **11** and **12** show yet another effect.

By changing the user parameters, an unlimited variety of parameters can be formed and eventually scribed on the fabrics.

Different geometric looking effects can be created using this tool. Each of the effects basically includes a plurality of

different geometrical objects arranged in different ways. FIGS. **30** and **31** show two additional images that have been created using this tool.

Another set of values can be created using mathematical functions based on fractal mathematics. Fractal mathematics are well known. For example, fractal mathematics are described in the Scientific American article by A. K. Dewdney "Computer Recreation: a Computer Microscope . . . Mathematics, "Scientific American (August 1985) pages 16 through 25.

Many different techniques and algorithms are known for generating images based on fractal mathematics. Two well-known techniques include Mandelbrot and Julia sets. Different fractal patterns are also known. A number of different fractal mathematics are described herein. Any of these techniques could be used, in addition to many other fractal techniques that are not specifically described herein.

A Mandelbrot fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. A general equation for the Mandelbrot fractal is of the general form $z_{n+1}=f(z_n)$, used to create a series of a complex variable. One example function is $f(z_n)=z_n^2+z_o$. This series in generated for every initial point z_o along some partition. Each point on the image can decay to 0, increase toward infinity, oscillate among a number of states, or change completely randomly. Each of the areas of the image can separately change, for example, in each area, the points can change according to a different function.

Another function, called a "biomorph" uses the function $f(z_n)=\sin(z_n)+z_n^2+c$. This kind of fractal may produce different functions based on the value of the constant "c".

Strange attractor fractals may shows values from a chaotic system. The series is formed as an equation of a complex variable or as two interrelated equations, one for the x and one for the y coordinate. An example function is

$$X_{n+1}=y_n-\sin(x_n)\ |bx_n-c|^{1/2}$$

$$Y_{n+1}=a-x_n$$

For strange attractors, the initial point does not matter, i.e.: all initial coordinates xo,yo result in the same image.

Another set is

$$x_n+1=\sin(ay_n)-\cos(bx_n)$$

$$y_n+1=\sin(cx_n)-\cos(dy_n)$$

This gives swirling tendrils that appear three-dimensional.

The Newton Raphson technique is based on the Newton Raphson method of finding the solution (roots) to a polynomial equation of the form

$$f(z)=\alpha_0+a_1Z+a_2z^2+K+a_mz^m=0$$

$$Z_n+1=Z_n-\frac{f(z_n)}{f'(z_n)}$$

where f'(zn) is the slope (first derivative) of f(z) evaluated at zn. To create a 2D image using this technique each point in a partition of the plane is used as initial guess, zo, to the solution. The point is colored depending on which solution is found and/or how long it took to arrive at the solution. Diffusion Limited Aggregation fractals can also be used in such a system. These fractals describe the diffusion and aggregation of zinc ions in an electrolytic solution onto electrodes, for example.

Fractal Geometry forms can also be used. These forms are based on geometric forms formed of lines, planes, rectangular volumes, arcs, cylinders, spheres, etc.

The system can also use fractal Landscapes based on line systems or "L-Systems", or based on polygons, also called "iterated function systems". This system carries out a set of contractive transformations on a plane of the form

$$\begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} x_{n-1} \\ y_{n-1} \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix}$$

Another technique uses chaos iterations of the form

$$x_n+1<-f(x_n, y_n)$$

$$y_n+1<-f(x_n, y_n)$$

According to a second tool set, different sets of fractal mathematics are used to create images. Different portions of these images can be selected. The images can then be magnified, or demagnified. Any different parts of the images can be selected. Also, any different parameters can be used within the image.

A user interface for the fractal mathematics is shown in FIGS. **13**. This allows selection of one of the different kinds of fractal mathematics, including those described above, and any others, using the selection tool **1300**. While this Figure only shows using Julia and Mandlebrot techniques, any other fractal mathematics technique can be used. The number of iterations is selected at **1305**, and the real and imaginary components of the mathematics are selected at **1310**. At **1320**, the user selects x and y minimum and maximum values. Using the values shown in FIG. **13**, the result shown in FIG. **14** is obtained. Figure pairs **15**/**16** and **17**/**18** show alternative parameter settings, and the results that can be obtained from those specific parameter settings.

Another mathematical tool uses blending and/or smoothing tools to modify the images that have been created. A blending tool carries out a modification on patterns that are created by any manual or automated method. The patterns are blended on a pixel-by-pixel basis. The blending can be carried out using any desired technique. One such technique is described below with reference to the flowchart of FIG. **19**.

Assuming that the pattern is based on k "colors", each pixel is assigned a value Z which is between 0 and k at 1900. The process of blending replaces each pixel's value with a weighted average of values of pixels in a neighborhood of a specified size. For a 3×3 neighborhood, the blending can replace each given pixel with a combination of that pixel as affected by values of its eight adjacent pixels. In **1905**, all of the neighboring pixels within the selected neighboring size are selected. Its values are obtained at **1910**, and the values are combined and weighted by values W_n. The weightings of the different pixels can be equal, can be unequal based on a specified direction and/or distance or a linear or non-linear relationship, or can be totally random. **1910** shows a mathematical operation of

$$\frac{\frac{Z1}{W1}+\frac{z2}{w2}+\frac{z3}{w3}\cdots+\frac{zn}{wn}}{N}$$

can take any of the values z_n and weight them by any desired amount w_n, and take an average of those values.

Two different kinds of blending can be used at **1920**: labeled herein as stable blending or unstable blending. A stable blend determines all updated pixel colors based on the pixel colors at the beginning of the blend process. An unstable blend performs updating based on pixel colors as they have been updated so far in the process.

A blend increment option at **1925** allows the color intensity assigned to a pixel to be greater than or less than that computed by the averaging process. The blend increment may be defined in terms of percentages, i.e., how much greater than or less than the averaging process.

A blanking parameter, shown at **1930**, specifies the number of neighboring pixels, or image areas that can be formed of multiple pixels, that must be non-blank before a blank pixel is allowed to become non-blank. This can provide useful control of the blending process, especially when abrupt lines exist in the pattern. Suppose, for example, a region includes a circle. If the blending were carried out without the blanking control, blank pixels that bordered the circle would be blended into the non-blank portion. This would unintentionally enlarge the circle. By setting this blanking parameter, blank pixels can be specially treated. This can keep the sharp edges and overall shape of geometrical objects.

Another part of the blanking option at **1930** allows selecting only pixels which are non blank to be changed.

Other size neighborhoods can be used. For example, further blending can be carried out by using a five by five neighborhood for example.

Weightings can be set in different ways. For example, the weight can be equal across the entire neighborhood. The weight can be unequal and weighted towards the center. Weights can also be set at random. In general, the weights can be set to any value, by assigning weights to pixels with each pixel Pn having a weight Wn.

Additional effects can be obtained using error diffusion. This process may be used as a dithering technique to improve the manipulation of the computer graphics. For example, this may approximate gray scale by black and white, or may be used for reducing color complexity. Error diffusion, for example, can be used for reducing 32-bit color to 8-bit color. Error diffusion may be used at **1935** as an option of the blend tool.

A specific example of error diffusion carries out a blending calculation for a specified pixel. Suppose this produces a value of 7.25. That value is then rounded to 7, and assigned to the given pixel. There is, however, an error in the rounding, here 0.25. This value is carried over as in increment to the blending calculation for the next pixel.

FIG. **29** shows a graphic image that has been created by a process beginning with a random distribution of randomly color pixels and completed with several applications of the blend tool.

Smoothing tools may include an "attach" tool and a "cleanup" tool shown as **1940**.

The attach tool examines currently blank pixels, as well as the eight neighboring pixels. The attach tool assigns a pixel under consideration to a user selected color, but only if a sufficient number of neighboring pixels are non-blank. That number may be a user set parameter.

The cleanup tool is used to reduce stray marks. Non-blank pixels are examined, and made blank, unless a specified sufficient number of neighboring pixels are non-blank. This number may be a user set parameter. This effect can reduce stray non-blank pixels that are isolated from other non-blank pixels. Therefore, the cleanup tool may make the image look less noisy.

A completely isolated non-blank pixel might be a pixel that is non-blank, in a neighborhood with one or more blank pixels. A slightly isolated non-blank pixel may have seven blank neighbors and one non-blank neighbor.

Many of the effect described herein are produced by experimentation using mathematical tools. As byproducts of the tools, especially byproducts of the fractal tool, stray portions may be left. The cleanup tool is therefore used to cleanup the results of the mathematical process.

The grain and annealing tools operate to blend pixels using a different paradigm than the blending tool.

The annealing tool shown at **1945** is an iterative procedure that changes a color based on the number of iterations where the color has stayed the same. A number of passes through a specified process is carried out. Each pass causes the color to be changed in some way. The way in which the color is changed can be based on any function or any other technique described herein.

Each pixel may also have a weight associated with the pixel. The weight is reset each time the color is changed during each iteration, the value of each weight is increased unless it is reset during that increment. Therefore, the weights increase based on the number of annealing operations for which the color has remained the same. Colors that have been constant for more annealing operations are given higher weight. Any pixel color that has remained constant for a user specified number of annealing operations may be considered fixed with respect to the annealing tool. At any point in a sequence of annealing operations, the color history can be reset to zero by the user.

The grain tool at **1950** adds to the techniques carried out by the annealing tool. However, the grain tool requires that a new color which is to be added to the image must be among those that already appear in the neighborhood. In this embodiment, after the weighted average color is computed, the new color may become that color in the neighborhood which is closest to the average value.

FIG. **19**B shows an example. A graphic image is created by a process beginning with the random distribution of randomly-color pixels. The image is completed using several applications of the grain tool and several applications of the annealing tool. Note that the grain tool tends to make the colors segregate into batches of the specific colors.

Another set of tools is based on cellular automata. Cellular automata is a branch of mathematics which allows modifying states of different parameters. These can be thought of as finite states machines which change the states of their cells, here the cells being pixels, step-by-step according to a set of rules.

A Boolean cellular automata is a collection of cells that can be in one of two states, on and off, 1 or 0. The states of each cell varies in time depending on the connections, called rules, between the cells. While there can be any arbitrary set of connections/rules governing the system, a number of examples are described herein.

A first example is a linear strip of cells where the output of each cell at each time is a function of a current state of the cell and a state of its neighbors. The cell can be open ended, or can have its ends connected together to form a continuous band.

If there are two neighbors then, a value of any particular cell has its value determined by three values; its state and the state of its neighbors. This leads to at most 8 different transitions. For example, the rules might be as follows:

$$000\rightarrow 0,\ 001\rightarrow 0,\ 010\rightarrow 1,\ 011\rightarrow 1,$$

$$100\rightarrow 1,\ 101\rightarrow 0,\ 110\rightarrow 0,\ 111\rightarrow 0$$

Another example of cellular automata is based on the well-known Pascals triangle.

A number of tools can be defined based on the cellular automata. Here, the percolate tool and life tool are defined by specifying rules by which the cells change their states.

The cellular automata tools can be used to modify any existing pattern, or to generate original patterns. These tools have been given names appropriate to the way in which they operate. For example, two tools are described herein that have the names "percolate" and "life".

The percolate tool examines each pixel, and gives it the highest possible color intensity based on the color of pixels in the specified neighborhood. Each color within the range of colors is assigned a color threshold value which is based on a parameter that is set by the user. Each pixel in the neighborhood is also assigned a weight; also based on parameters set by the user.

Beginning with the highest color level, and working downward towards another color level, the following test is performed.

For a given trial color level, called color level K, the weights of pixels in the neighborhood for which the actual pixel color is greater than or equal to K are summed. The sum of the weights is compared with a threshold value for color K. If the sum is greater than or equal to the threshold value, then the pixel under consideration is assigned to color level K. Otherwise, the trial color level K. is decreased by one and the test is repeated.

The percolate tool may also produce unique texturing effects when applied to an existing pattern. It can be used to produce a wide variety of lattice designs when sequentially applied to a series of patterns which begin with a pattern consisting of one or more isolated non-blank pixels. A large number of user set parameters can be defined, including the trial color level, weights, type of comparison for example greater than or equal to, and the like. The number of effects which can be set by the system therefore becomes extremely large.

Another cellular automata tool is called the life tool. This tool is operated in a matter which is analogous. Decreases in color level are provided in addition to increases that occur with the percolate tool. Again, a large number of effects become possible.

FIG. **20** shows a graphic image created by a process beginning with a random distribution of circles of random colors followed by several applications of the percolate tool. FIGS. **21–26** show graphic images created by a process that begins with one or more isolated pixels and several applications of the percolate tool. FIG. **27** shows a graphic image created by a process that begins with one or more isolated pixels and several applications of the life tool followed by several applications of the percolate tool. FIG. **28** shows a graphic image created by a process that begins with a graphic created with the modular level sets tool followed by several applications of the percolate tool.

The above has described each control being separately executed. In addition, however, the file may be saved as a specified file which includes the ability to execute any and all of these functions. In this embodiment, the pattern file may be saved as a file of type ".ppx".

FIGS. **33** through **35** shows controls on the main screen of the overall system used according to the present system. A pattern file **3300** is defined. This may be a file that has been opened, or may be a new file which it being newly presented. The contents of the pattern file, either the newly presented file or the file which is opened, will be used to modify the look of some material e.g. a garment, using a specified marking element such as a laser. In **3310**, the operating parameters of the laser are set. This may include the speed of the laser, and the laser scale factor. The pattern may also be scaled in **3315**. For example, a small pattern may be created but may be increased in size when it will be written on to the textile material. The pattern dimension on the laser may also be set.

Many fabrics have directional characteristics, e.g. the characteristics of the twill of the fabric. For example, denim includes twills. Therefore, the drawing direction of the laser may affect the way the pattern looks on the material, especially on denim. **3325** sets the drawing direction of the laser. **3330** sets the way the color change is set. The color change may be set either randomly or deterministically. At **3335**, the number of drawing directions may be changed. The drawings may be carried out from a number of different characteristics.

As described above, the system assumes that each color in the image that is created represents a power level. The colors may be selectively associated with the power level at **3340**. For example, each color is shown such as colors **123** and **4**. Each color may also be associated with a power level. Other effects are also shown in FIG. **33**. The boundary line is set at **3342**. The boundary may be minimized at **3345**, and the image may be low pass filtered at **3350**. To the extent that random numbers are used, a seed may be entered at **3355**. As conventional, the pattern may be edited saved, changed version, or displayed using the user interface control shown as **3360**. When the user interface **3365** is called up, this brings up the editing screen shown in FIG. **34**. This editing screen enables the image to be seen and changed. A number of the drawing tools described above may also be used. A close-up of these drawing tools is shown in FIG. **35**. Note that the FIG. **34** screen shows a pattern based on the Julia/Mandelbrot. Therefore, the selection based tools **3505** are all grayed out, and only the fractal set tool **3510** is shown as being selected. This may also bring up the specific fractal set interface shown in FIG. **13**. Each of the pattern control tools described above may also be included in the editing screen.

Although only a few embodiments have been disclosed in detail above, other modifications are possible. For example, while it may be considered preferred to use this system for modifying the look of apartment using laser, it may also be possible to modify the garment using other techniques. Other techniques which are subsumed by this invention may include chemical bleaching or other color altering, screen-printing, and discharge printing. In any of these systems, the image which is produced by the system may be in color, and subsequently associated with power levels a which are used for applying the color changing technique. In one embodiment, the color images themselves may be applied using a printing technique. Different kinds of material handling systems can be used. These material handling systems can include fabric presented as a continuous Web, fabric presented as precut panels, and/or fabric presented as a completed garment.

An advantage of this system is better run of products can be made where all products are precisely the same. Another run can be made where all products are unique to the specified products.

All such modifications are intended to be encompassed within the following claims, in which:

What is claimed is:

1. A method, comprising:

allowing a user to enter and/or change each of a plurality of different parameters;

carrying out a mathematical operation based on said parameters to form values which are individualized for each of a plurality of areas; and

using said values to control a laser to change a look of a textile material according to said values.

2. A method as in claim 1, wherein said mathematical operation includes a fractal operation.

3. A method as in claim 2, wherein said fractal representation includes at least one of a Mandelbrot set and a Julia set.

4. A method as in claim 2, further comprising allowing the user to select specified values associated with the fractal representation.

5. A method as in claim 4 wherein said specified values include minimum and maximum values.

6. A method as in claim 1, wherein said mathematical operation includes cellular automata.

7. A method as in claim 1, wherein said mathematical function includes both a polynomial function and a trigonometric function.

8. A method as in claim 1 wherein said mathematical operation uses a modulus function.

9. A method as in claim 1, wherein said mathematical operation uses an integer function.

10. A method as in claim 1, wherein said mathematical operation includes user changeable parameters, at least one of which is a multiplication parameter, and another of which is an addition parameter.

11. A method as in claim 10, wherein said mathematical operation includes an operation of the form $ax^n+bx^{n-1}\cdots$.

12. A method as in claim 1, wherein said allowing comprises providing the user interface including a plurality of different mathematical options, and allowing the user to select at least one of said mathematical options, and at least one user selectable parameter associated with said at least one mathematical options.

13. A method as in claim 12, wherein said mathematical options include at least a polynomial function, a trigonometric function, and parameters for said polynomial function and said trigonometric function.

14. A method as in claim 12, further comprising allowing selection of scaling of an image using a scale control.

15. A method as in claim 1, wherein said mathematical operation includes processing said parameters using modular level sets.

16. A method as in claim 15, further comprising using said values to form an image indicative of the values on said areas, wherein each pixel is defined as coordinates, and the value of the pixel is defined according to a polynomial function F(x,y).

17. A method as in claim 16, wherein said parameterized function is a trigonometric function.

18. A method as in claim 15, wherein said values are calculated as MOD[(INT(A*F(X,Y)+B),M], where said parameters include at least A, B and M.

19. A method as in claim 18, wherein F is of the form $F=ax^n+bx^{n-1}+\ldots$.

20. A method as in claim 15 wherein said modular level sets are of the form ax^n+bx^{n-1}.

21. A method as in claim 20 further comprising using said values to form an image indicative of the values on said areas.

22. A method as in claim 21, wherein said image is formed of pixels, and further comprising allowing pixels in a neighborhood to be blended according to a specified weighting.

23. A method as in claim 22, wherein said specified weighting includes equal weighting for all pixels.

24. A method as in claim 22, wherein said specified weighting comprises weighting of the form

$$\frac{\frac{Z1}{W1}+\frac{z2}{w2}+\frac{z3}{w3}\cdots+\frac{zn}{wn}}{N}.$$

25. A method as in claim 22, wherein said blending is carried out based on pixel colors which exist at a beginning time of a blending process.

26. A method as in claim 22, wherein said blending is carried out based on pixel colors as they have been updated at any given point in the blending process.

27. A method as in claim 22, further comprising setting a blanking value which specifies a number of neighboring pixels that must be nonblank before a blank pixel is allowed to be nonblank.

28. A method as in claim 21, wherein said image is formed of pixels, and further comprising finding non blank pixels which have a neighborhood comprised of a specified number of blank pixels, and adjusting the value of said non blank pixels based on said finding said specified number.

29. A method as in claim 28, further comprising allowing setting of said specified number.

30. A method as in claim 29, wherein said adjusting the value comprises changing said non-blank pixels into blank pixels.

31. A method as in claim 21, further comprising modifying said image using an iterative process in which portions of the image are processed based on effects of other iterations in the image.

32. A method as in claim 31, wherein said modifying comprises modifying a color of pixels of the image based on a number of times that the color has been modified during said other iterations.

33. A method as in claim 32, further comprising assigning a weight to each pixel, and increasing said weight based on the number of times that the color of the pixels stays the same.

34. A method as in claim 32, further comprising defining allowable colors for the image.

35. A method as in claim 34, wherein said allowable colors include only those colors which already exist in the image.

36. A method as in claim 34, wherein said modifying comprises modifying the color, finding an interim color, finding an allowable color which is closest to said interim color, and defining each pixel as being said allowable color which is closest to said interim color.

37. A method as in claim 21, wherein said mathematical effect is an effect based on cellular automata.

38. A method as in claim 37, wherein said mathematical effect defines each of the plurality of image areas based on both the image areas and neighbors of the image area.

39. A method as in claim 38, wherein said mathematical effect gives each pixel a highest intensity value based on both said pixel and said neighbors.

40. A method as in claim 39, wherein said mathematical effect comprises, for a given color level, summing weights of pixels in a neighborhood, determining if on actual pixel color has a specified relation to said weights, and continuing said summing until said actual pixel color has said specified relation.

41. A method as in claim 40, wherein said specified relation includes greater than.

42. A method as in claim 40 wherein said specified relation includes less than.

43. A method as in claim 21, further comprising storing effect codes indicative of an effect of the laser on micro-

structure of a specified fabric, and wherein said image simulates the effect of the laser on the specified fabric.

44. A method as in claim **43**, wherein said effect codes represent effects based on a direction of a weave of the fabric.

45. A method as in claim **43**, wherein said fabric is denim, and said effect codes are based on the direction of a weave of the denim.

46. A method as in claim **21**, further comprising associating each of a plurality of laser power levels with the color of the image.

47. A method as in claim **46** wherein each color is a gray scale value.

48. A method as in claim **46**, wherein said laser power level that is associated with a color is an output energy per unit time.

49. A method, comprising:

allowing a user to enter and/or change each of a plurality of different parameters;

carrying out a mathematical operation based on said parameters to form values which are individualized for each of a plurality of areas;

using said values to control a laser to change a look of a textile material according to said values; and

wherein said values represent amounts of change to be caused to said textile material, and are calculated according to said mathematical operation.

50. A method as in claim **49**, wherein said values represent an amount of energy to be delivered by said laser for a specified unit of textile material.

51. A method as in claim **49**, wherein said values represent an amount of energy to be delivered by said laser per unit time to said textile material.

52. A laser processing system, comprising:

a user interface, indicating entry elements allowing a user to enter and/or change each of a plurality of different parameters and displaying said parameters;

a processor, receiving said parameters, and carrying out a mathematical operation based on said parameters, and carrying out a mathematical operation based on said parameters to form values which are individualized for each of a plurality of areas and uses said values to control a laser to change a look of a textile according to said values.

53. A system as in claim **52**, wherein said values represent an amount of energy to be delivered by said laser for a specified unit of textile material.

54. A system as in claim **52** wherein said mathematical operation uses a modulus function.

55. A system as in claim **52**, wherein said mathematical operation uses an integer function.

56. A system as in claim **52**, wherein said mathematical operation includes user changeable parameters, at least one of which is a multiplication parameter, and another of which is an addition parameter.

57. A system as in claim **56**, wherein said mathematical operation includes an operation of the form ax^n+bx^{n-1} . . . .

58. A system as in claim **52** wherein said user interface allows a user to select between at least a fractal mathematics set, a cellular automata mathematics set or a modular level sets mathematics set.

59. A system as in claim **58**, wherein said specified values include minimum and maximum values.

60. A system as in claim **52**, further comprising using said values to form an image indicative of the values on said areas.

61. A system as in claim **60**, wherein said processor creates an image using said parameters and cellular automata mathematics.

62. A system as in claim **60**, wherein each pixel is defined as coordinates, and a value of the pixel is defined according to a polynomial function F(x,y).

63. A system as in claim **62**, wherein said parameterized function is a trigonometric function.

64. A system as in claim **60**, wherein said mathematical function includes both a polynomial function and a trigonometric function.

65. A system as in claim **60**, wherein said values represent an amount of energy to be delivered by said laser per unit time to said textile material.

66. A system as in claim **60**, wherein said allowing comprises providing the user interface including a plurality of different mathematical options, and allowing the user to select at least one of said mathematical options, and at least one user selectable parameter associated with said at least one mathematical options.

67. A system as in claim **66** wherein said mathematical options include at least a polynomial function, a trigonometric function, and parameters for said polynomial function and said trigonometric function.

68. A system as in claim **66**, further comprising allowing selection of scaling of an image using a scale control.

69. A system as in claim **60**, wherein said image is formed of pixels, and wherein said processor processes said image to find non blank pixels which have a neighborhood comprised of a specified number of blank pixels, and adjust a value of said non blank pixels based on said finding said specified number.

70. A system as in claim **69** wherein said user interface also allows setting of said specified number.

71. A system as in claim **70**, wherein said processor adjust the pixels by changing said non-blank pixels into blank pixels.

72. A system as in claim **60**, wherein said processor creates an image using a fractal image based on said parameters.

73. A system as in claim **72**, wherein said fractal representation includes at least one of a Mandelbrot set and a Julia set.

74. A system as in claim **72**, wherein said user interface allows a user to select specified values associated with the fractal representation.

75. A system as in claim **60**, wherein said processory creates an image using said parameters using modular level sets.

76. A system as in claim **75**, wherein said modular level sets are of the form $ax^n+bx^{n-1.}$

77. A system as in claim **75**, wherein said values are calculated as MOD[(INT(A*F(X,Y)+B),M], where said parameters include at least A, B and M.

78. A system as in claim **77**, wherein F is of the form $F=ax^n+bx_{n-1}+$ . . . .

79. A system as in claim **60**, wherein said image is formed of pixels, and wherein said processor carries out an operation to allow pixels in a neighborhood to be blended according to a specified weighting.

80. A system as in claim **79**, wherein said specified weighting includes equal weighting for all pixels.

81. A system as in claim **79**, wherein said specified weighting comprises weighting of the form

$$\frac{\frac{Z1}{W1}+\frac{z2}{w2}+\frac{z3}{w3}\ldots+\frac{zn}{wn}}{N}.$$

82. A system as in claim **79**, wherein said blending is carried out based on pixel colors which exist at a beginning time of a blending process.

83. A system as in claim **79**, wherein said blending is carried out based on pixel colors as they have been updated at any given point in the blending process.

84. A system as in claim **79**, further comprising setting a blanking value which specifies a number of pixels that must be nonblank before a blank pixel is allowed to be nonblank.

85. A system as in claim **60**, wherein said processor modifies said image using an iterative process in which portions of the image are processed based on effects of other iterations in the image.

86. A system as in claim **85**, wherein said modifying comprises modifying a color of pixels of the image based on a number of times that the color has been modified during said other iterations.

87. A system as in claim **86**, wherein said processor assigns a weight to each pixel, and increasing said weight based on the number of times that the color of the pixels stays the same.

88. A system as in claim **86**, further comprising a memory storing allowable colors for the image.

89. A system as in claim **88**, wherein said allowable colors include only those colors which already exist in the image.

90. A system as in claim **60**, wherein said processor carries out said mathematical effect by giving each pixel a highest intensity value based on both said pixel and said neighbors.

91. A system as in claim **90**, wherein said processor carries out said mathematical effect by, for a given color level, summing weights of pixels in a neighborhood, determining if on actual pixel color has a specified relation to said weights, and continuing said summing until said actual pixel color has said specified relation.

92. A system as in claim **91**, wherein said specified relation includes greater than.

93. A system as in claim **91**, wherein said specified relation includes less than.

94. A system as in claim **60**, further comprising a memory storing effect codes indicative of an effect of the laser on microstructure of a specified fabric, and said processor uses said effect codes to simulate an effect of the laser on the specified fabric.

95. A system as in claim **94**, wherein said effect codes represent effects based on a direction of a weave of the fabric.

96. A system as in claim **95**, wherein said fabric is denim, and said effect codes are based on the direction of a weave of the denim.

97. A system as in claim **60**, wherein said processor associates each of a plurality of laser power levels with a color of the image.

98. A system as in claim **97**, wherein each color is a gray scale value.

99. A method of processing a textile material, comprising:

allowing a user to enter parameters to be used as part of a mathematical function;

using said values to calculate an image that is based on said values and that simulates an effect that a laser controlled according to said mathematical function will have on a textile material; and

displaying said image on the user interface.

100. A method as in claim **99**, wherein said mathematical function is a fractal function.

101. A method as in claim **99**, wherein said mathematical function is a modular level set function.

102. A method as in claim **99**, wherein said mathematical function is a cellular automata function.

103. A method as in claim **99**, further comprising controlling a laser, using said values, to produce said effect on a textile material.

104. A method as in claim **99**, further comprising further processing said image using an iterative function.

105. A system, comprising:

a computer;

a user interface which accepts input values and carries out a mathematical function based on said input values and displays a simulated image based on said input values, and produces output signals indicative of said image; and

a controlled laser, producing an output power at different controlled positions which is dependent on values of said image.

106. A system as in claim **105**, wherein said mathematical function is a fractal function.

107. A system as in claim **105**, wherein said mathematical function is a modular level sets function.

108. A system as in claim **105**, wherein said mathematical function is a cellular automata function.

109. A method, comprising:

obtaining parameters associated with a fractal function;

using said parameters along with said fractal function to calculate values of picture elements and locations for said picture elements;

displaying an overall image that is based on said picture elements and locations; and

using said values of picture elements and locations to control an automated system to change a look of a textile material according to said image.

110. A method as in claim **109**, wherein said using comprises controlling a laser to apply different power levels according to said image, wherein each part of the image represents a different laser power level.

111. A method, comprising:

obtaining parameters associated with a modular level set function;

using said parameters along with said modular level set function to calculate values of picture elements and locations for said picture elements;

displaying an overall image that is based on said picture elements and locations; and

using said picture elements and locations to control an automated laser system to change a look of a textile material according to said image.

112. A method as in claim **111**, wherein said using comprises controlling a laser to apply different power levels according to said image, wherein each part of the image represents a different laser power level.

113. A method, comprising:

obtaining parameters associated with a cellular automata function;

using said parameters along with said cellular automata function to calculate values of picture elements and locations for said picture elements;

displaying an overall image that is based on said picture elements and locations; and

using said picture elements and locations to control an automated laser system to change a look of a textile material according to said overall image.

114. A method as in claim **113**, wherein said using comprises controlling a laser to apply different power levels according to said image, wherein each part of the image represents a different laser power level.

115. A method, comprising:

displaying a user interface indicative of a plurality of parameters which can be entered as to form a fractal pattern;

at a specified time and in response to a specified cue, forming a display indicative of a simulated image of said parameters forming said fractal pattern on a specified type of material; and

forming an output signal adapted for driving a laser processing unit to produce said fractal pattern on said specified material.

116. A method as in claim **115**, wherein said fractal pattern is one of a Julia fractal set or a Mandelbrot fractal set.

117. A method as in claim **115**, wherein said forming comprises forming an output signal for driving a laser.

118. A method as in claim **115**, wherein said forming comprises producing an output signal for driving an automated printing technique.

* * * * *

EXHIBIT 3

US006819972B1

(12) **United States Patent**
Martin et al.

(10) **Patent No.: US 6,819,972 B1**
(45) **Date of Patent: Nov. 16, 2004**

(54) **MATERIAL SURFACE PROCESSING WITH A LASER THAT HAS A SCAN MODULATED EFFECTIVE POWER TO ACHIEVE MULTIPLE WORN LOOKS**

(76) Inventors: **Clarence H Martin**, 290 Eastchester Ct., Gahanna, OH (US) 43230; **Darryl J. Costin**, 29261 Notingham Ct., Westlake, OH (US) 44145

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 468 days.

(21) Appl. No.: **09/653,997**

(22) Filed: **Sep. 1, 2000**

Related U.S. Application Data

(60) Provisional application No. 60/157,904, filed on Oct. 5, 1999.

(51) **Int. Cl.**[7] **G06F 19/00**

(52) **U.S. Cl.** **700/166**; 700/131; 700/132; 219/161.68; 219/121.69

(58) **Field of Search** 700/130, 131–132, 700/133, 129, 137, 142, 166, 119, 122, 127; 219/121.68, 121.69, 121.85, 14.85

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,017,423	A	*	5/1991	Bossmann et al.	428/224
5,436,027	A	*	7/1995	Offer	427/10
5,567,207	A	*	10/1996	Lockman et al.	8/444
5,652,805	A	*	7/1997	Ooenoki et al.	382/141
5,899,964	A	*	5/1999	Ooenoki et al.	702/150
5,916,461	A	*	6/1999	Costin et al.	219/121.68
5,990,444	A		11/1999	Costin	219/121.69
6,002,099	A	*	12/1999	Martin et al.	219/121.69
6,252,196	B1		6/2001	Costin et al.	219/121.69

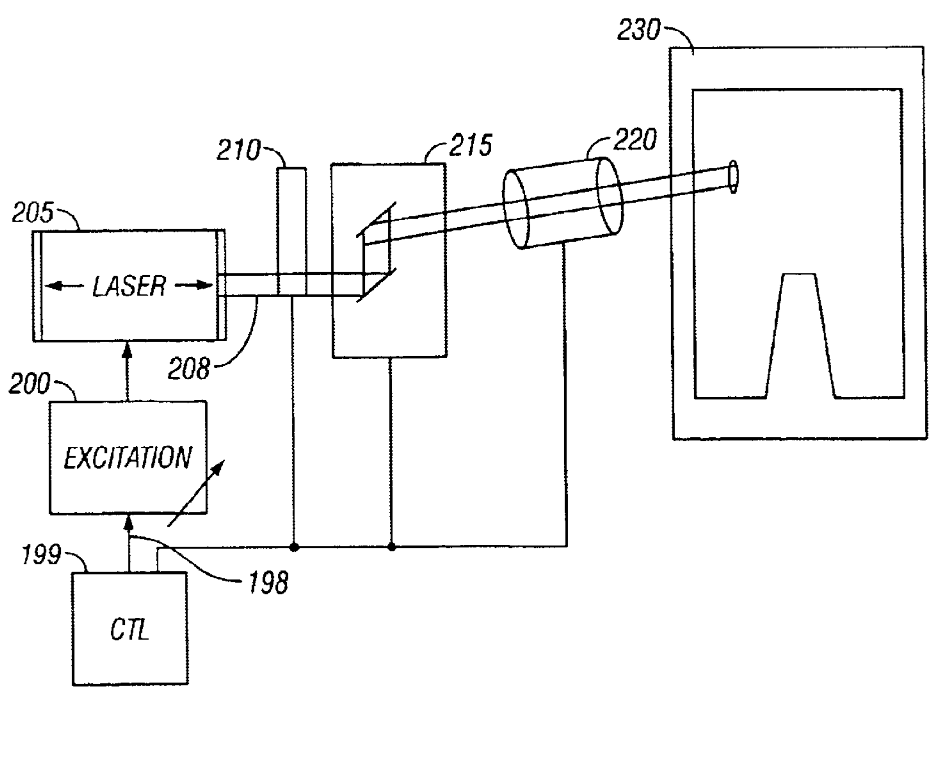
* cited by examiner

Primary Examiner—Ramesh Patel

(57) **ABSTRACT**

Techniques which enable changing certain amount of energy being applied from a laser to a material during scan lines of the laser. Energy can be applied to a material to change its look. Different energies can be applied within a single scan line to the material. A display can represent the pattern, by showing different areas of change to the material as different colors/looks on the display. For example, the color of the display can represent the amount of energy being applied to a specific position represented by that color. Since the amount of energy that is applied can change within a single scan line, and in fact may change multiple times within that scan line, this enables freely setting the characteristics.

95 Claims, 13 Drawing Sheets



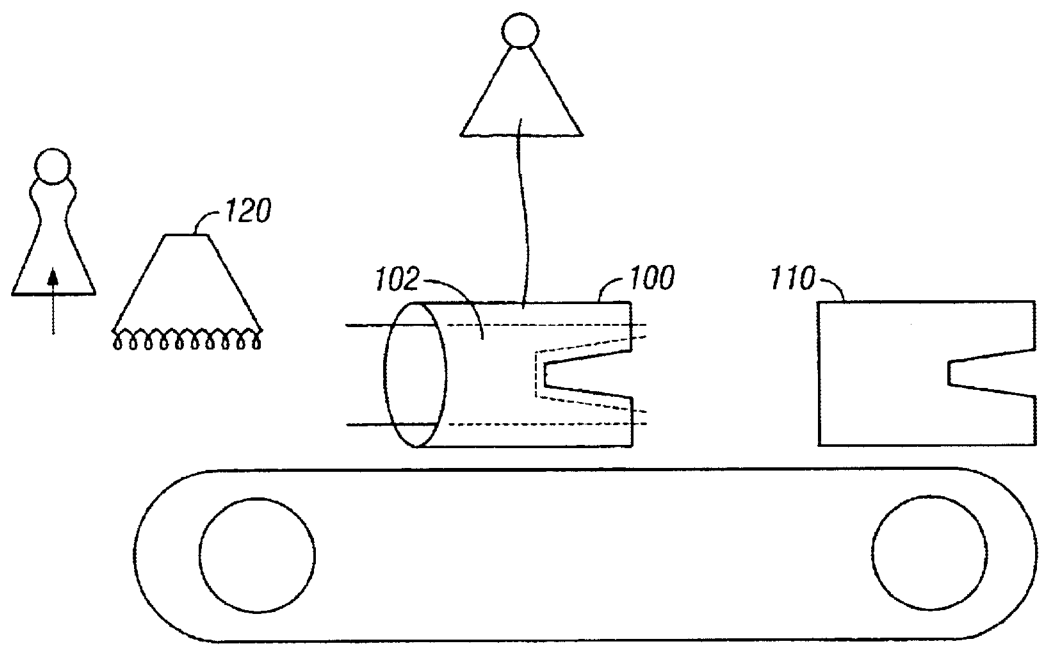

120
102
100
110

FIG. 1

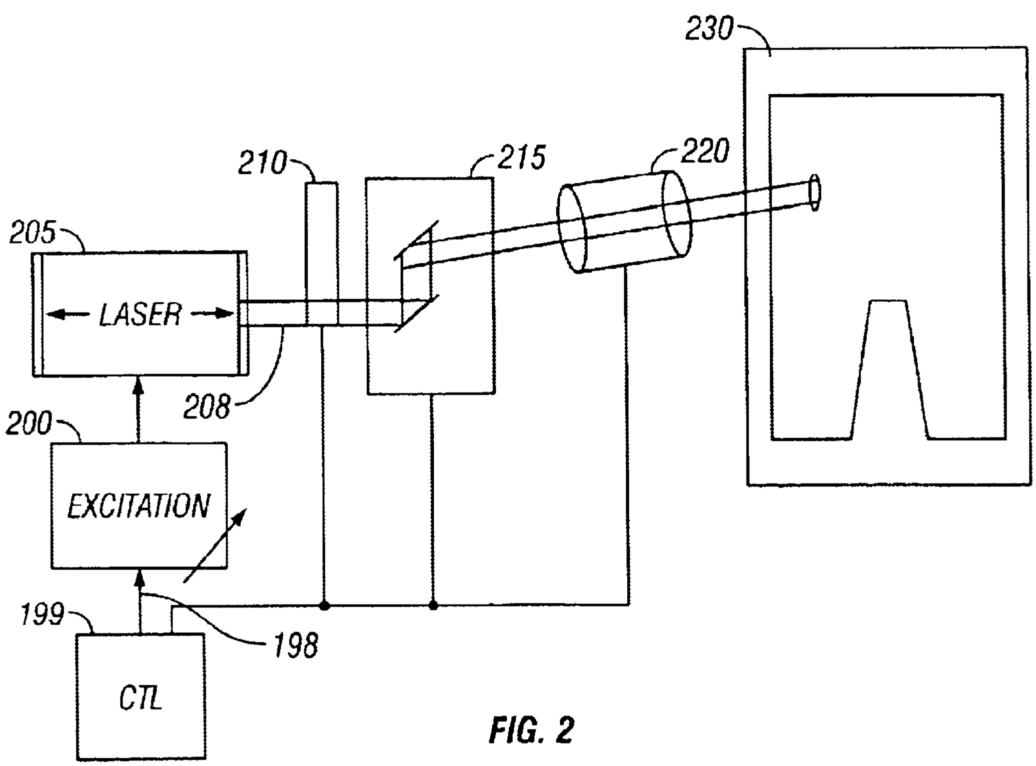

230
210
215
220
205
LASER
208
200
EXCITATION
199
198
CTL

FIG. 2

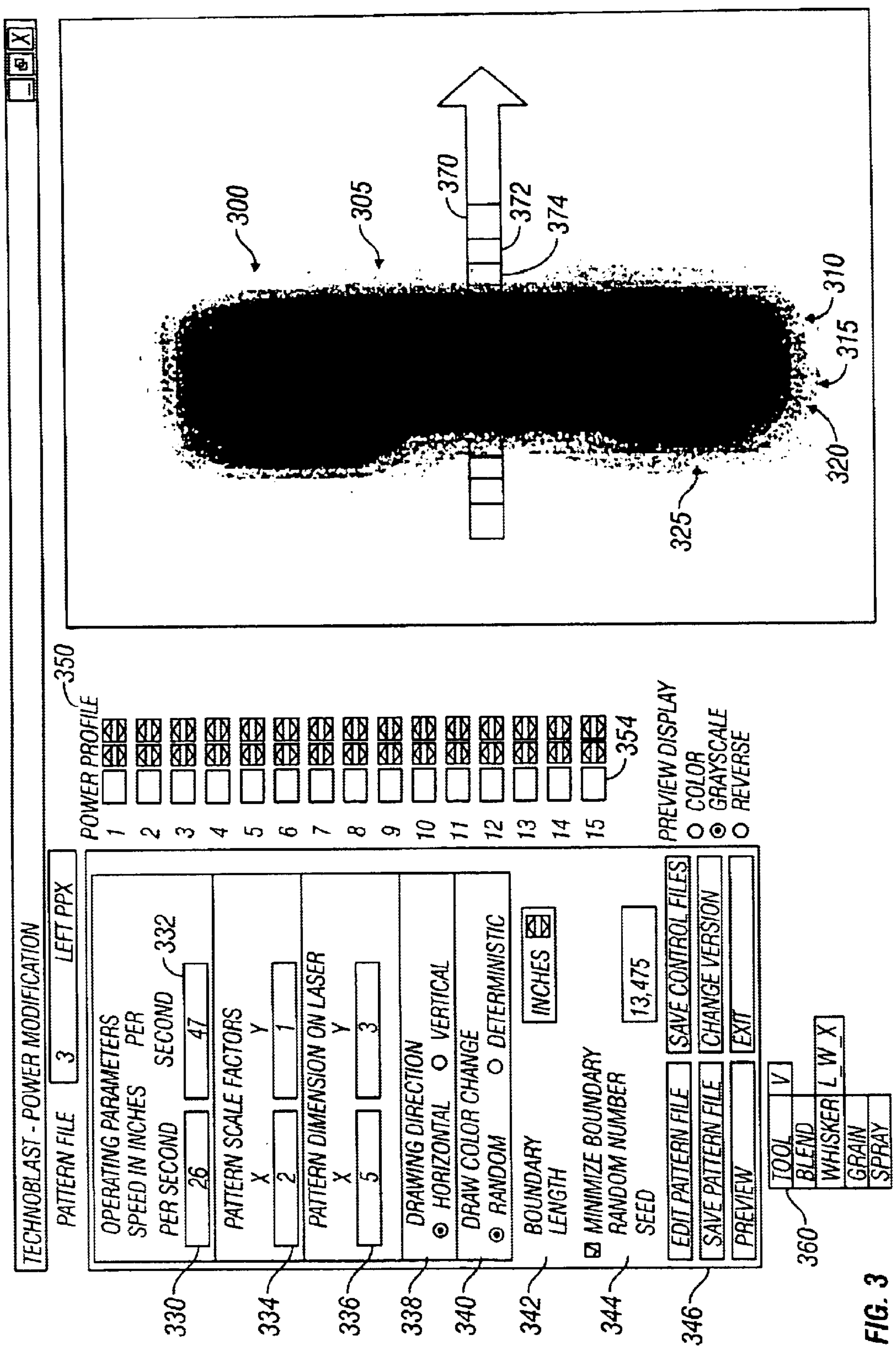

TECHNOBLAST - POWER MODIFICATION
PATTERN FILE
3
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES
PER SECOND
26
PER SECOND
47
PATTERN SCALE FACTORS
X
2
Y
1
PATTERN DIMENSION ON LASER
X
5
Y
3
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
INCHES
MINIMIZE BOUNDARY
RANDOM NUMBER SEED
13,475
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE
TOOL
V
BLEND
WHISKER
L_W_X
GRAIN
SPRAY
300
305
310
315
320
325
330
332
334
336
338
340
342
344
346
350
354
360
370
372
374

FIG. 3

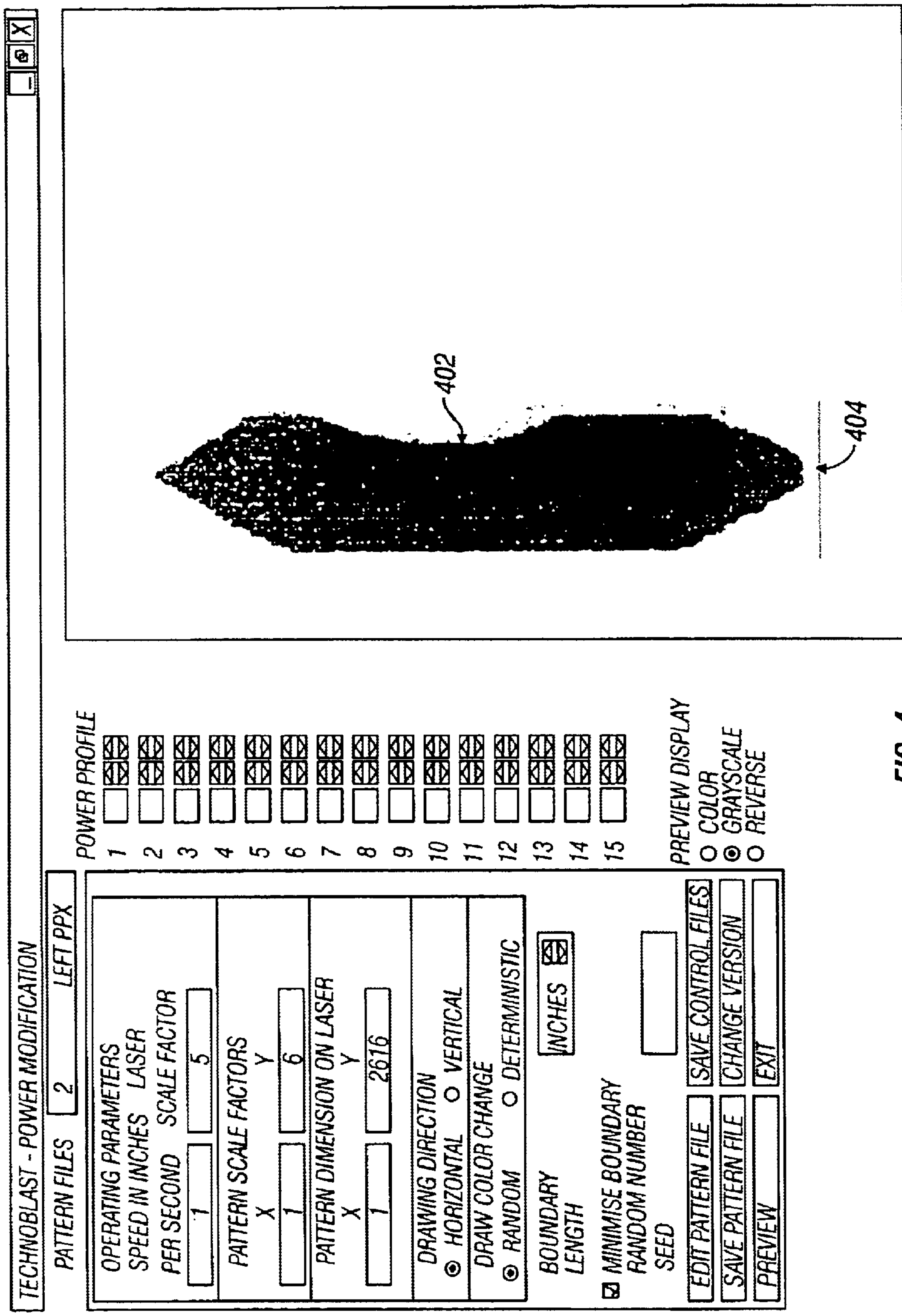

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
2
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
1
5
PATTERN SCALE FACTORS
X
Y
1
6
PATTERN DIMENSION ON LASER
X
Y
1
2616
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE
402
404

FIG. 4

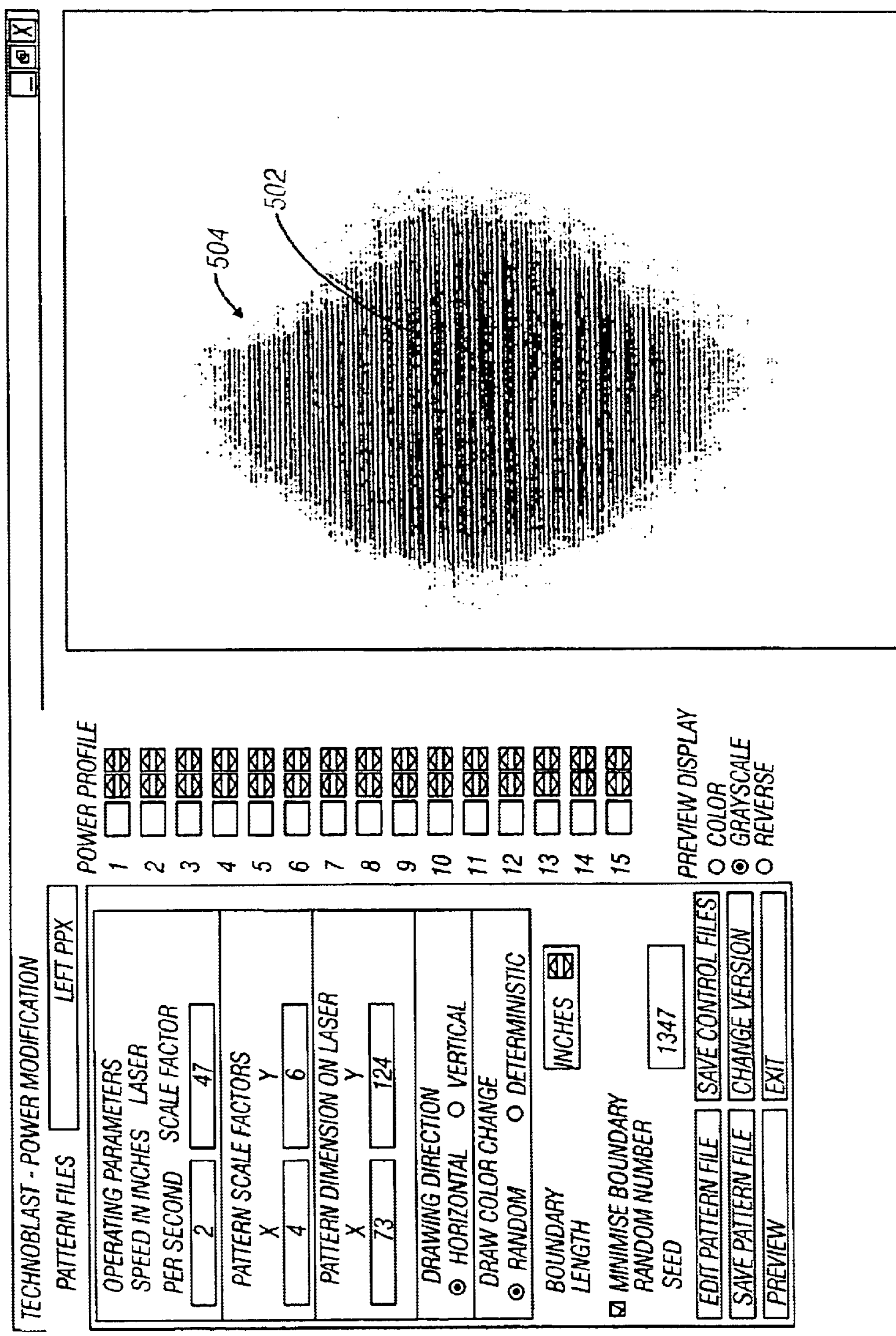

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
2
47
PATTERN SCALE FACTORS
X
Y
4
6
PATTERN DIMENSION ON LASER
X
Y
73
124
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
1347
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE
504
502

FIG. 5

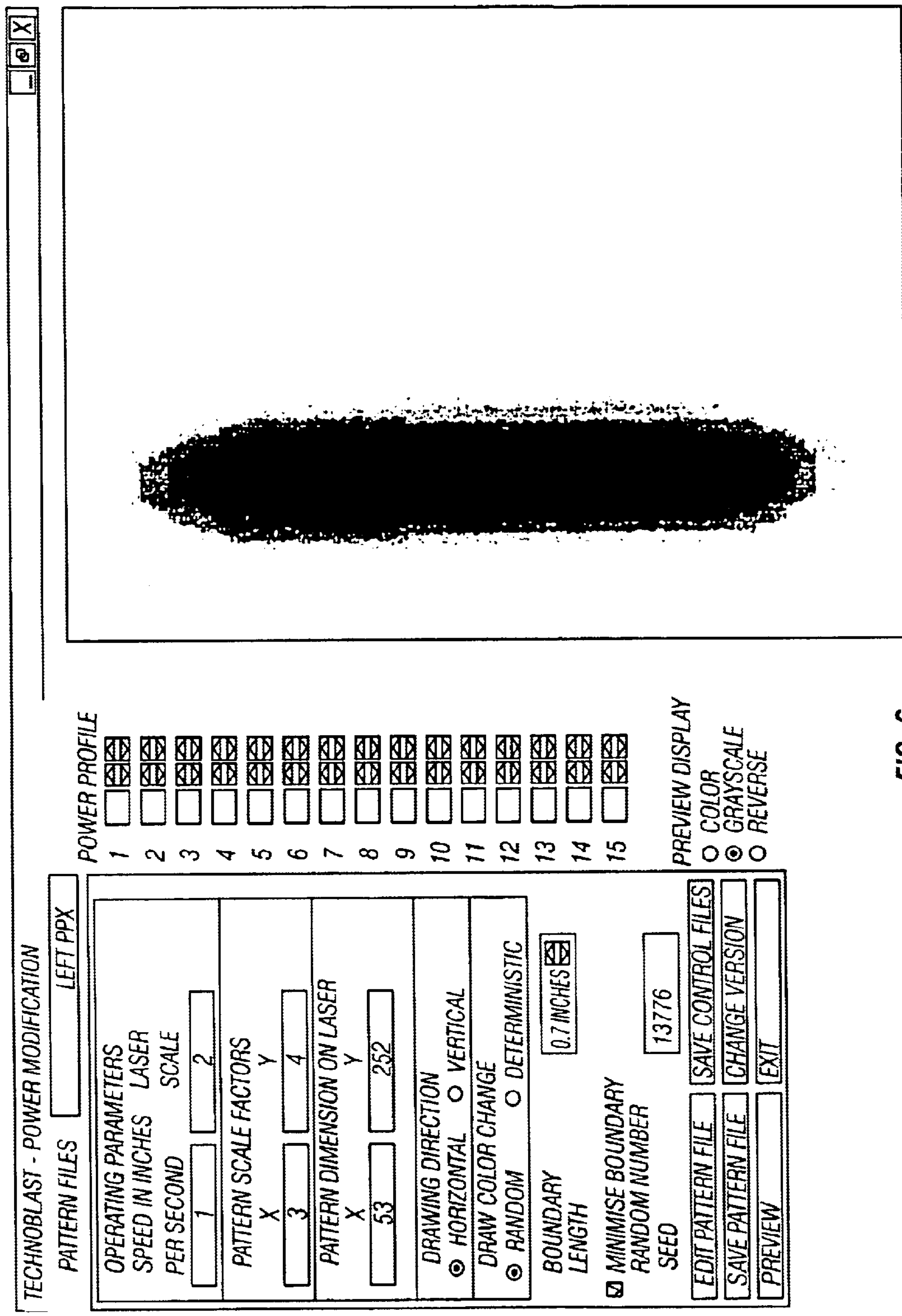

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
53
252
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 6

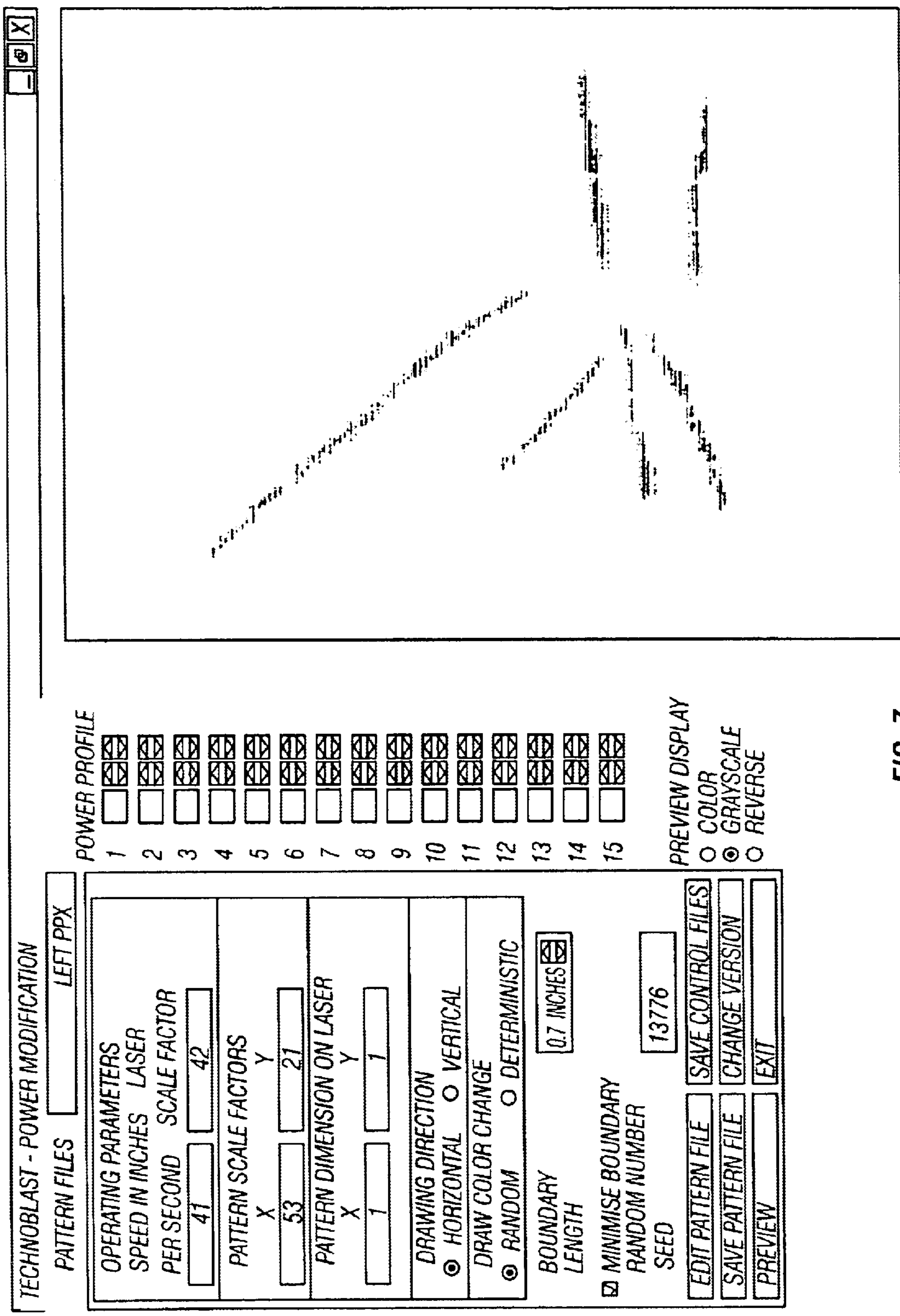

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
41
42
PATTERN SCALE FACTORS
X
Y
53
21
PATTERN DIMENSION ON LASER
X
Y
1
1
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 7

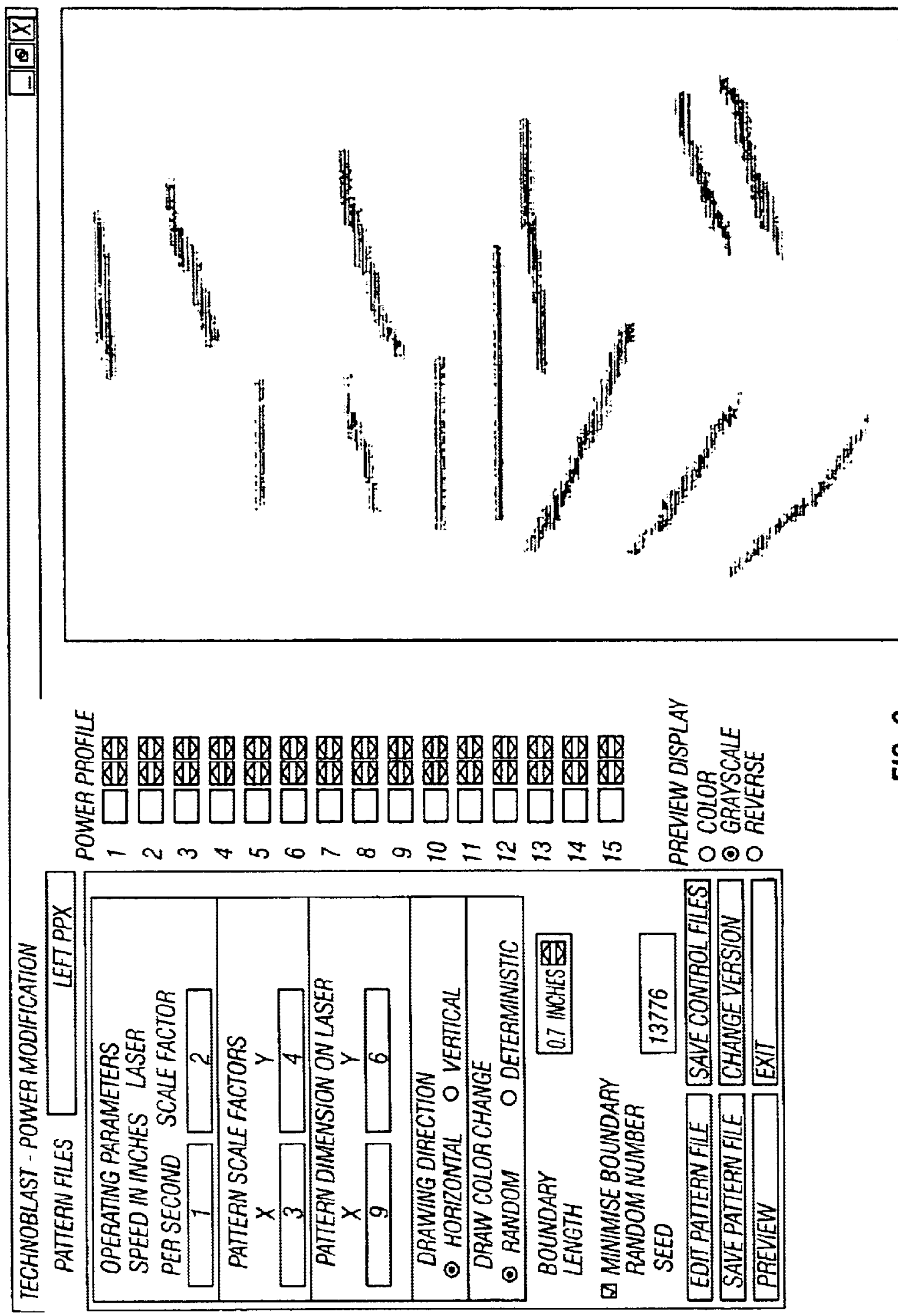

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES
PER SECOND
LASER
SCALE FACTOR
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
9
6
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY
LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER
SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 8

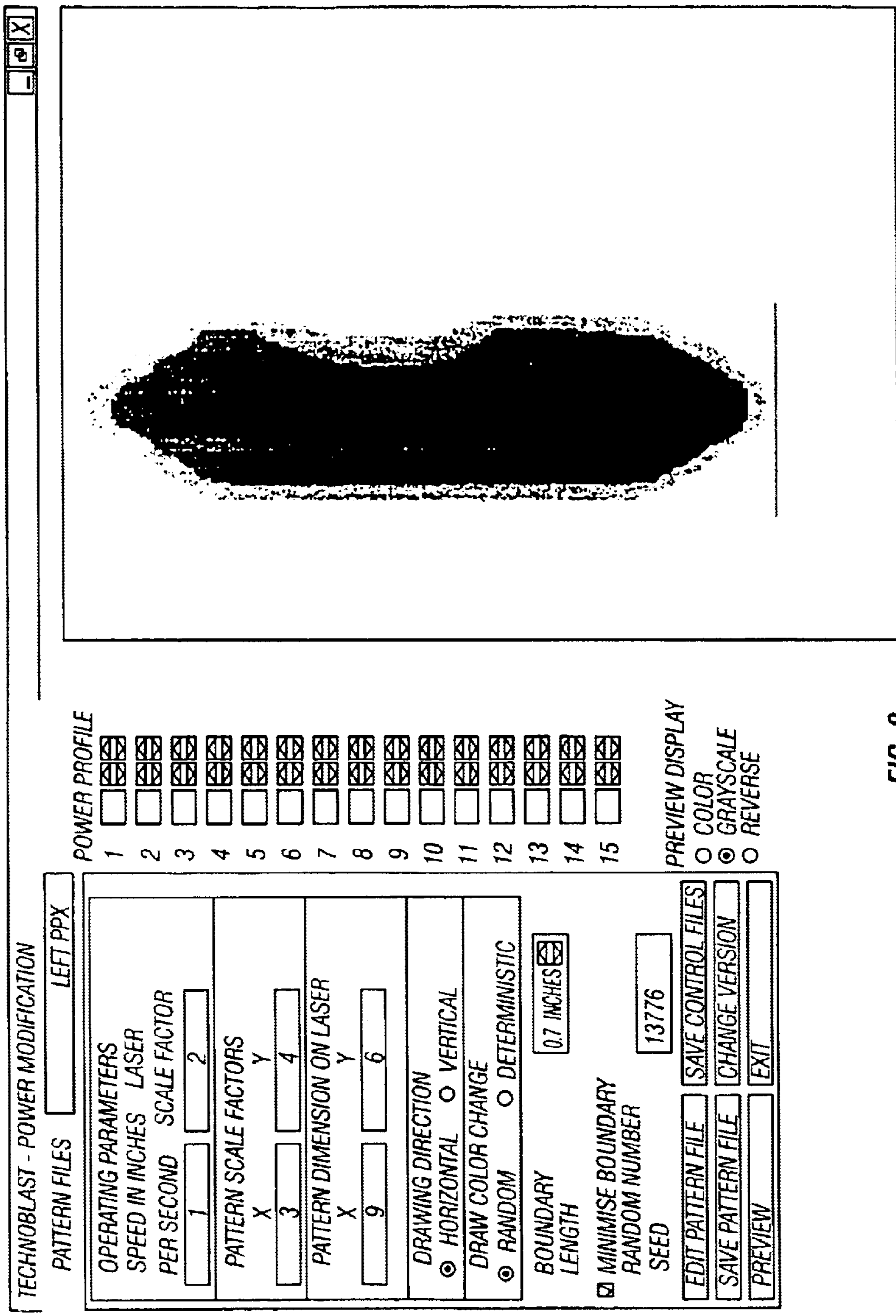
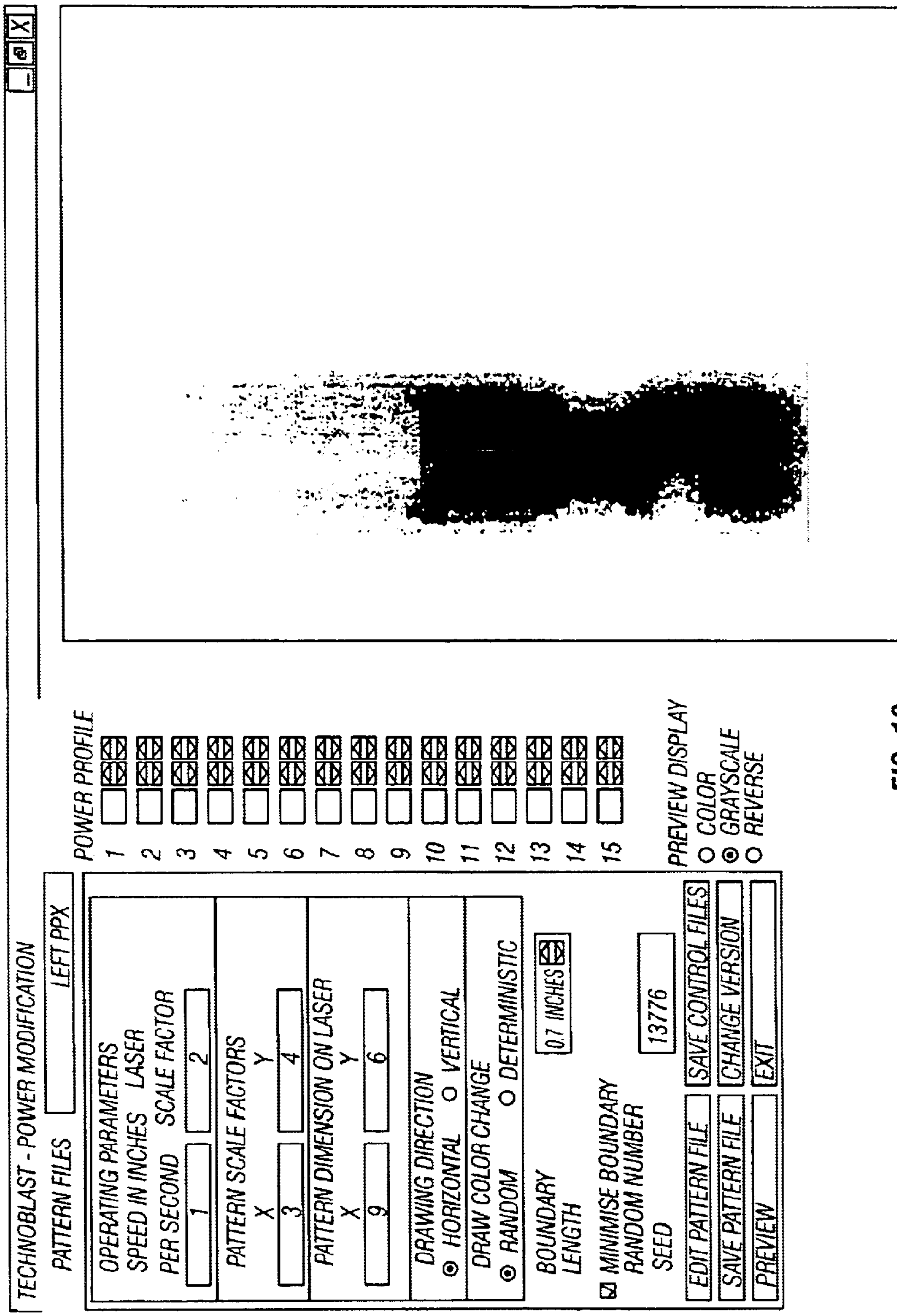

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
9
6
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 9



TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
9
6
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 10

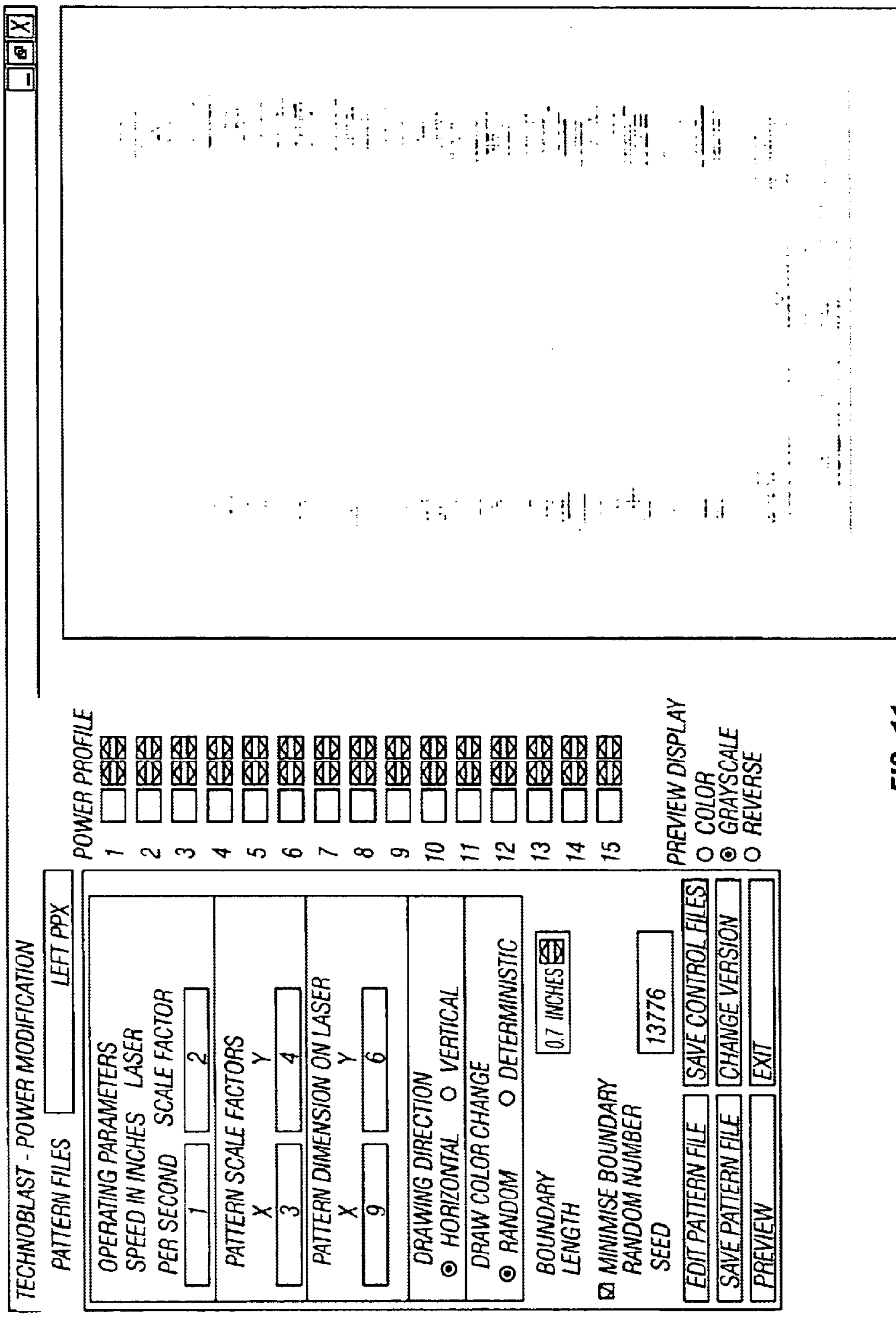

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES PER SECOND
LASER SCALE FACTOR
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
9
6
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE

FIG. 11

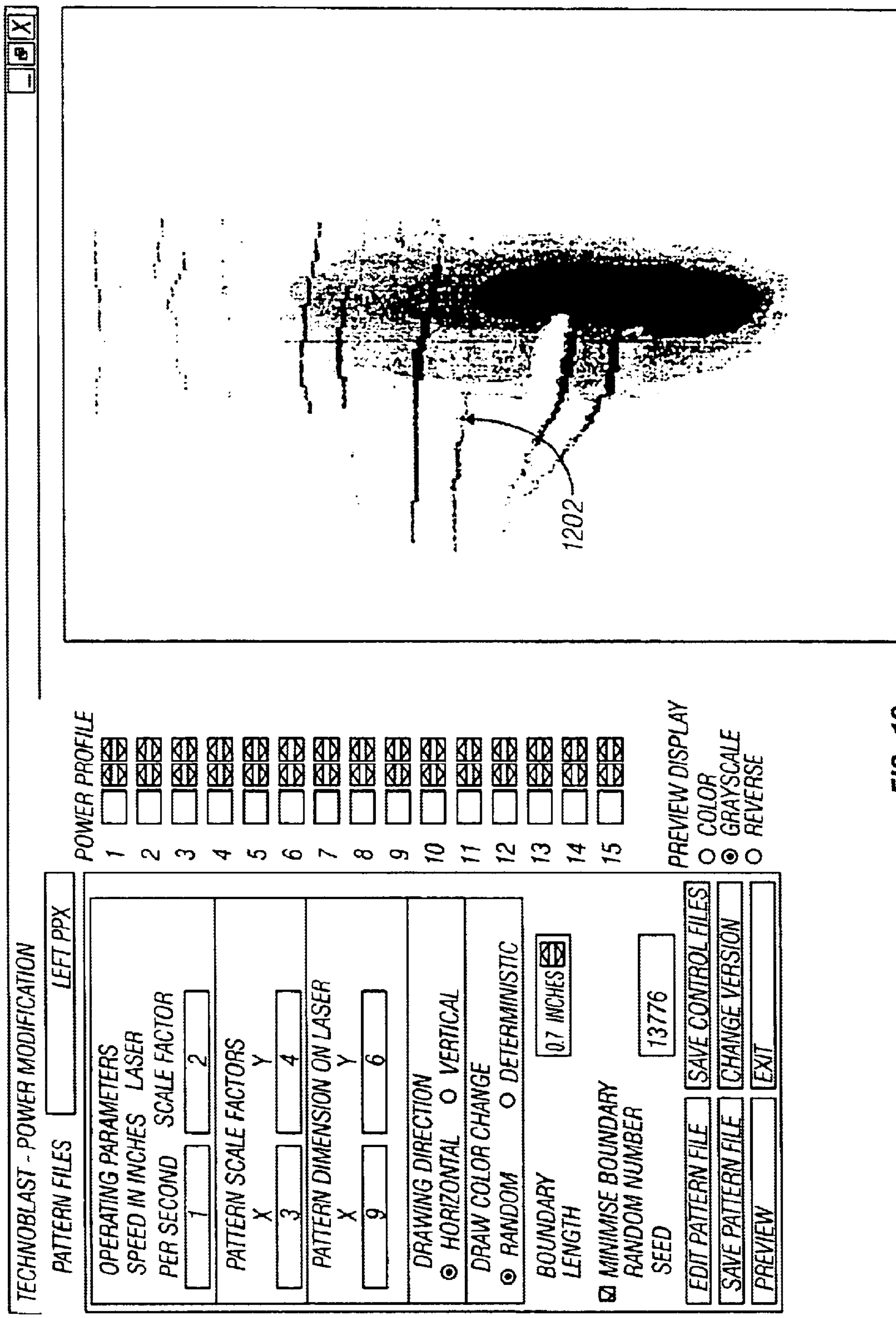

TECHNOBLAST - POWER MODIFICATION
PATTERN FILES
LEFT PPX
OPERATING PARAMETERS
SPEED IN INCHES
PER SECOND
LASER
SCALE FACTOR
1
2
PATTERN SCALE FACTORS
X
Y
3
4
PATTERN DIMENSION ON LASER
X
Y
9
6
DRAWING DIRECTION
HORIZONTAL
VERTICAL
DRAW COLOR CHANGE
RANDOM
DETERMINISTIC
BOUNDARY
LENGTH
0.7 INCHES
MINIMISE BOUNDARY
RANDOM NUMBER
SEED
13776
EDIT PATTERN FILE
SAVE CONTROL FILES
SAVE PATTERN FILE
CHANGE VERSION
PREVIEW
EXIT
POWER PROFILE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
PREVIEW DISPLAY
COLOR
GRAYSCALE
REVERSE
1202

FIG. 12

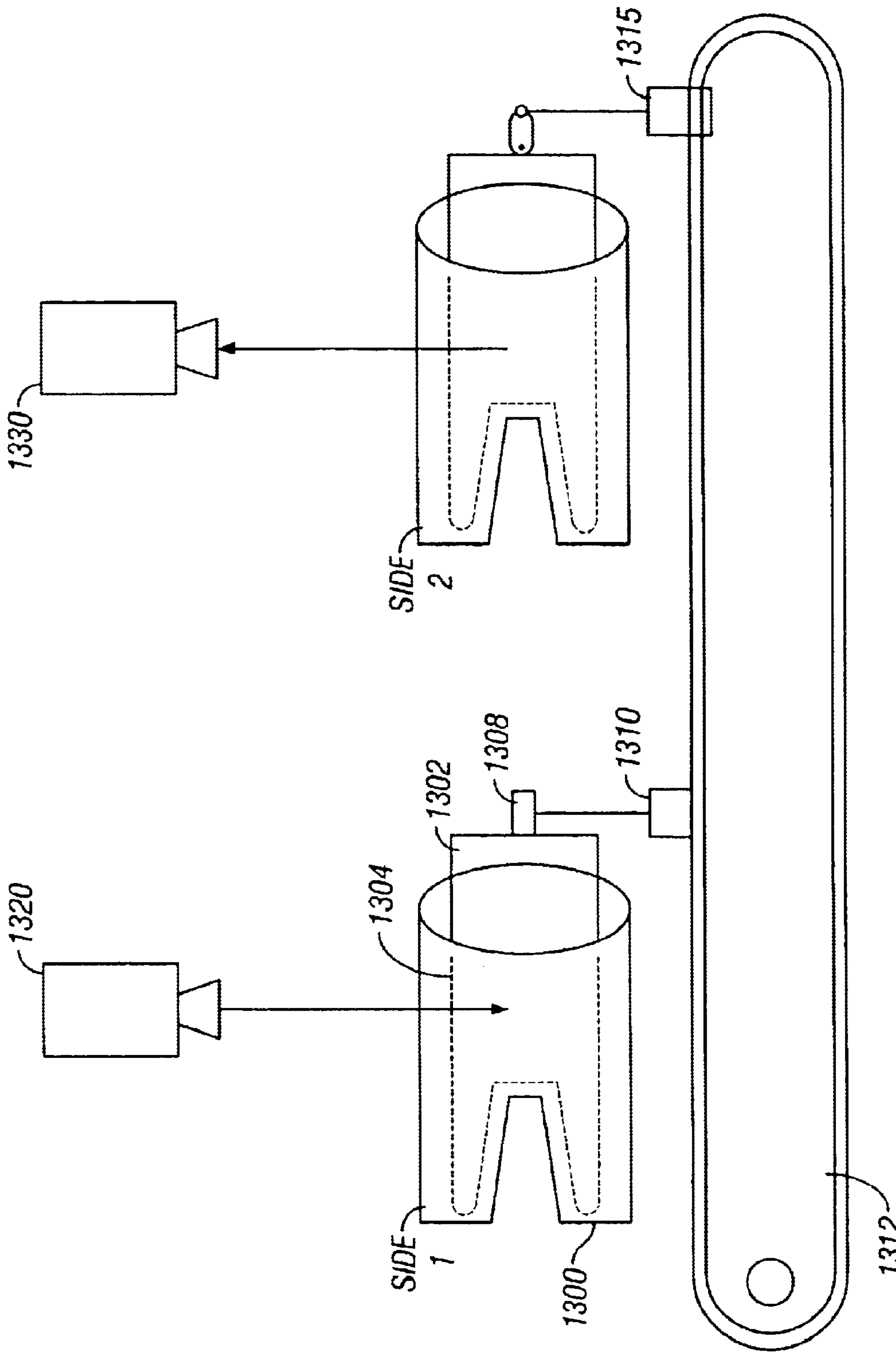


FIG. 13

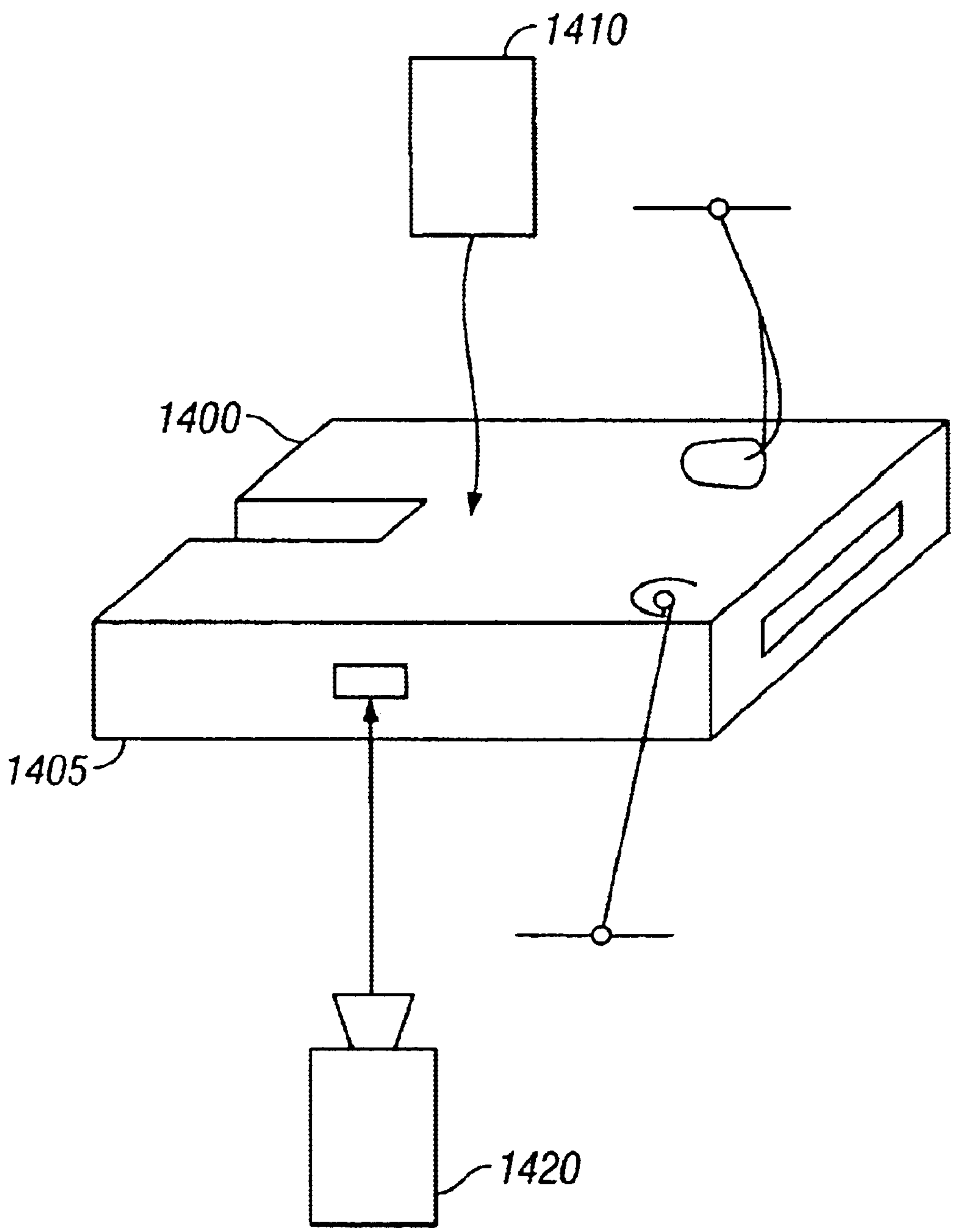


FIG. 14

MATERIAL SURFACE PROCESSING WITH A LASER THAT HAS A SCAN MODULATED EFFECTIVE POWER TO ACHIEVE MULTIPLE WORN LOOKS

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the U.S. Provisional Application No. 60/157,904, filed on Oct. 5, 1999.

BACKGROUND

Denim and other material garments have often been processed to make them look worn. Consumers have shown a desire to purchase broken-in garments.

Currently available techniques of processing such garments include mechanical sandblasting with sand or other abrasive; hand, mechanical, or robotic rubbing, and others. The effects may include local abrasion which is a wear pattern from below the waist to below the knee section. Another effect is global abrasion, which describes a wear pattern from below the waist to the cuff. "Whiskers" are a term which describes the wear that occurs along the creases and hem of the article during wear. Yet another worn look is a rectangular area marked on the rear pocket of the jean, which simulates the worn look caused from carrying a wallet in the back pocket. Yet another worn look is referred to as "frayed", where the degree of wear is so severe that the individual threads of the cotton fiber are exposed. Such a pattern section may even have holes in the denim fabric.

The sandblasting process for local and global abrasion may use sandblasting equipment to abrade the denim jeans with sand particles or other abrasive media. This process blasts sand particles from a sandblasting device to a pair of jeans. The random spatial distribution of the sand creates a special appearance in a treated area that is referred to as "feathered". The abrasion in the feathered area varies from light along the perimeter of the pattern, e.g., the edges and top of the pattern, to heavy in the center of the pattern. This unique appearance may simulate the look of denim jeans that have been worn for a considerable time.

However, the sandblast process has a number of problems and limitations. For example, the process of blasting sand or other abrasive media presents environmental and health issues. Typically, a worker needs to wear protective gear and masks to reduce the impact of inhaling airborne sand. The job is considered to be a hazardous job, and may cause high employee turnover.

The individual skill of the operator may also be critical in reducing the scrap rate associated with the sandblast process. This has the additional effect of increasing certain costs of labor for the sandblast operator which are typically higher than the labor rate for other employees in the denim finishing plant, since their skill may be important. The actual blasting process may occur in a room which is shielded from other areas in the manufacturing facility.

Further environmental issues arise with the cleanup and disposal of the sand.

The sandblasting process is an abrasive process, which causes wear to the sandblasting equipment. Often, the equipment needs to be replaced on a yearly basis or even more frequently. This, of course, can result in added capital, maintenance and installation expense.

Also, new designs such as shadow effects along the top or bottom of the whisker are difficult to impossible to obtain with the conventional sandblasting processes.

All in all, the sandblasting process may cost in excess of $1.00 per pair of jeans, due to the cost of labor, materials, and scrap produced, and environmental clean up required. It is difficult to duplicate the exact placement of the sandblast pattern from one garment to the next due to the variability of the process itself and the variability from one laborer to another.

The sandblast process can also adversely affect the tear and tensile properties of the denim jeans due to the abrasion of the sand on the denim. It is not uncommon for the sandblast process to reduce the tear and tensile strength of the denim by as much as 50%. Further, the tear and tensile strength variation following sandblasting is high due to the uncontrollability of the abrasive process. Some manufacturers even need to test the tear and tensile properties of the denim at specific locations where the abrasion is the least to even pass the apparel company standards for tear and tensile strength.

Other approaches to creating worn looks present their own problems. In the case of whiskers or frayed looks, manufacturers may rely upon very labor intensive, expensive and slow hand rubbing or sanding processes where the whiskers or frayed looks are applied to the denim by hand sanding, sometimes with a rotating drill such as a DREMEL™ tool. In addition to the labor costs associated with such a process, this hand sanding operation is often associated with defects after washing, where the sanding of the individual whiskers on the denim may be too little or too much resulting in a low quality product. Some manufacturers have even tried to use robotic sanding processes to avoid these problems, albeit at considerable capital investment and limited flexibility.

Despite the above shortcomings, sandblasting and rubbing processes remain in wide use because the market desires worn look denim.

The present assignee has disclosed laser processing of denim, e.g. in U.S. Pat. Nos. 5,990,444; 6,002,099 and 5,916,961. These techniques enable using a laser to change the look of a textile product.

SUMMARY

In recognition of the above, the inventors propose new laser scribing devices and techniques to simulate specified worn looks on fabrics and garments.

One aspect includes using a laser to scribe lines on a garment, where the energy density per unit time of the laser causes the garment to change color to varying degrees from indigo blue or black to white or grey. Both the individual scanned lines and different sections of a lazed pattern can have washing, where the sanding of the individual whiskers on the denim may be too little or too much resulting in a low quality product. Some manufacturers have even tried to use robotic sanding processes to avoid these problems, albeit at considerable capital investment and limited flexibility.

Despite the above shortcomings, sandblasting and rubbing processes remain in wide use because the market desires worn look denim.

The present assignee has disclosed laser processing of denim, e.g. in U.S. Pat. Nos. 5,990,444; 6,002,099 and 5,916,961. These techniques enable using a laser to change the look of a textile product.

SUMMARY

In recognition of the above, the inventors propose new laser scribing devices and techniques to simulate specified worn looks on fabrics and garments.

One aspect includes using a laser to scribe lines on a garment, where the energy density per unit time of the laser causes the garment to change color to varying degrees from indigo blue or black to white or grey. Both the individual scanned lines and different sections of a lazed pattern can have varied energy density per unit time. The variation in energy density per unit time can be controlled by changing the power, speed, distance, or duty cycle of the laser as the lines are scribed on the material.

Other aspects are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects will now be described in detail with respect to the accompanying drawings, wherein:

FIG. **1** shows an overall lasing system;

FIG. **2** shows a controllable laser system;

FIG. **3** shows a control screen for a specified worn look;

FIGS. **4-12** show control screens for different specified worn looks;

FIG. **13** shows a material delivery system with automatic turnover; and

FIG. **14** shows a material delivery system with a dual sided laser.

DETAILED DESCRIPTION

The described system and method teaches a system for producing worn looks on textile materials and/or garments that are made from these textile materials. These worn looks can include abrasion effects which simulate the look of a worn garment, whisker effects, frayed effects, as well as any other effect which is produced on a garment or another product made from a textile material and which makes the textile material look more like a used textile material. In addition, entirely new looks are possible from this invention that cannot be reproduced from the conventional sandblasting or rubbing process. This is done using a number of techniques described in detail herein.

A first technique uses a laser. The output of the laser is caused to move across a textile material. The applied energy from the laser changes the look of the textile material without undesirably burning, punching through or otherwise harming the textile material. The basic operations of applying energy from a laser are described in U.S. Pat. No. 5,990,444.

In the disclosed system, the effective applied energy of the laser, e.g, the energy density per unit time ("EDPUT") of the laser, is changed while the laser is scribing a line across the material ("on the fly"). The line which is scribed can be a straight line or a waveform of any shape; however, a line is formed by the laser traversing the textile or garment from one edge to another.

The present application introduces the concept of effective applied energy. This includes the amount of energy that is effectively applied to an area of a material. That area can be any size or shape. The "effective applied energy" can include edput, but also includes changing scan line speed, power level or speed level or duty cycle level of the laser. It includes change the distance of the laser to the material, which can defocus the laser, and thereby change the EDPUT. It also includes effective applied power being applied in multiple sessions or times, by applying multiple passes, e.g. of fixed power etc. The effect is to apply more energy to some areas than to others.

Another element produces a control sequence that simulates a statistically random property of particle distribution such as would be produced by a sandblasting process. This technique is used with a user interface program, which enables the designer to paint the information on an interface screen. The image on the screen is applied to the material with a laser. Another aspect of the technique enables use of a much higher power laser than previous systems of this type.

As described above, the amount of change that the laser produces on the textile material is based in part on the effective applied energy to the material; previously described in U.S. Pat. No. 5,990,444 as the energy density per unit time level of the laser relative to the material. EDPUT depends on power of the laser, spot size and scan speed of the laser system relative to the material.

A laser output of the laser is used to scribe multiple lines across the material. The line can repeat, i.e. in a zigzag or triangle wave shape. According to the present system, the EDPUT level is changed while a line is being scanned across the material. That is, at some point between the ends of at least one scan line, the EDPUT is different than it is at either end of the line. The controller system controls the change of EDPUT level by controlling the parameters which control EDPUT (power or duty cycle or speed or distance).

The EDPUT delivered to the material may be changed in different ways. A first way is to change the wattage or power of the laser output in a continuous or discontinuous fashion. A laser relies on light bouncing back and forth inside a laser cavity. The level of excitation of the laser itself may be variable in certain lasers. Hence excitation unit **200** may actually be variable to vary the power output of the laser. Thus, this first way to change the EDPUT level of the laser directly controls the level of excitation of the laser in an analog manner.

The other EDPUT controls do not change the actual laser power output, but instead change the effective amount of energy density per time that arrives on the material. Another control of EDPUT is via duty cycle control. The control drive **198** to the excitation unit **200** can be cycled between on, and off, at a relatively quick rate. The rate of turning on and off must be fast relative to the movement of the laser. This technique changes the duty cycle of the output of the laser **205**, effectively controlling the laser to deliver a different average power level. In any short time, i.e. in the amount of time it takes the laser to traverse a distance equal to one or two times the width of the laser beam, the duty cycle may be adjusted multiple times. The effective applied energy density per unit time may therefore be adjusted by this system, since the root mean square of the power varies with time just as if the power were changed itself.

The laser can also use an adjustable shutter, as shown as element **210**. This shutter may use a fast piezoelectric element to open and close an aperture through which the laser beam **208** passes. The mechanical shutter can also turn on and off the shutter relatively quickly. Hence, this mechanical shutter forms an alternate way of changing the duty cycle of laser application.

The laser beam is applied to the garment and caused to move relative to the garment by a laser moving element **215**. This laser moving element can include moving mirrors, or some other way of changing the laser movement. In this embodiment, the controller may also produce an output that controls the scanning speed of the laser. By changing the speed of the laser, the EDPUT changes along the course of its line, even if the output power of the laser stays constant.

Yet another way of changing the EDPUT is via changing the output size of the laser beam. FIG. **2** shows a zoom lens assembly **120** which is electrically controllable. The con-

troller **199** may produce an output signal that changes the relative position of the lenses to one another and thereby electrically changes the spot size.

Alternatively, the platform **230** holding the material may itself be moved. Placing the garment on a curved surface is yet another way to change the EDPUT levels by intentionally causing the laser beam to come out of focus (lowering the EDPUT) at the curved sections if the center of the section is exactly in focus.

Yet another way to change the EDPUT is to make multiple passes or laser scans on different segments of the pattern. Those sections which have multiple passes will have higher effective EDPUTs if all other laser operating parameters are held constant.

This system is used to attempt to mimic naturally-occurring processes. Worn looks that are obtained from a conventional laser scribing process may look overly uniform in some circumstances. This may be referred to as a contrived or pasted look. The goal, however, is to produce as natural a look as possible.

U.S. Pat. No. 5,916,461 describes using a probability density function to randomly turn the laser on and off to simulate "feathering" on the material.

The inventors recognized, however, that continuously and discontinuously changing the EDPUT level within any laser scan line can even further improve the effect. By so doing, this system alters the amount of change or abrasion to the textile material, as the laser scribes individual lines on the textile material. This invention provides complete control of the degree of feathering. The degree of feathering can be continuously controlled then by changing the EDPUT levels anywhere in the pattern. Control of feathering in this way can achieve a worn looks that appears authentic.

One aspect of this system, therefore, produces a worn look or other desired look on a textile material by scanning a laser across a textile, and uses the laser to change a color of the material, where the effective power density per unit time of the laser is changed at least once within a scan line.

According to one aspect, typically sandblasted garments are examined. This examination reveals different shapes and wear patterns. These patterns are basically non-uniform in nature. A high degree of feathering, or variation of the material (abrasion), across the edges and top and bottom of a pattern is observed, either directly by a human examiner, or via an automated examination process. Different concentrations of wear along different areas of the pattern are also observed. The present system stores information from this observation in the memory **195** that is associated with the controller. This information includes geometric information about the wear pattern to be scribed. The information also includes the look of the actual scanned portion.

This look is then translated into an specified type of parameter matrix. The matrix can be an EDPUT matrix, a power matrix, a duty cycle matrix or a speed-matrix, for example. The inventors have found by experimentation that the amount of energy per unit time that is applied to any specific area of certain textiles may change the look in proportion to the applied amount of energy. This proportion need not be a linear proportion. The look change may also include the look after washing.

Different patterns can hence be scanned, e.g. using a scanner or camera. The scanner can evaluate each of the sections on the garment, here shown as denim jeans. The system may evaluate, using the total resolution of the scanner, the color of that section. A look up table can be established relating the color of certain materials to the applied EDPUT or power or duty cycle or speed or distance. In this way, the EDPUT for each area on the jeans can be established.

This information can be used to form the above-described matrix, storing any of the above-described parameters. This matrix can then be used as the information in the memory **195** which drives the controller to drive the laser. In this way, different EDPUT levels can be applied to different sections of the textile based on the information that is obtained by observing some other material.

Alternately, the user can examine the wear pattern and manually enter the changes in EDPUT (power, speed, duty cycle or distance) that are associated with the change in abrasion along the pattern geometry. These techniques can replicate any desired look, and can also produce an entirely new look.

In another aspect, existing looks can be edited. The look is scanned as noted above to form a matrix. The matrix can then be edited to keep the desirable parts, and change other parts.

Examples of the distribution of EDPUT along a single scanned line may look as shown in Table I.

TABLE I

EDPUT Calculations for a Scanned Line

	Power (watts)	Spot (mm)	Area (mm2)	Speed mm/sec	EDPUT watts-sec/mm3
Scan #1:					
Start of Scan	150	0.30	0.0707	25,000	0.08
First Section of Scan	190	0.30	0.0707	25,000	0.11
First Quarter of Scan	225	0.30	0.0707	25,000	0.13
Second Quarter of Scan	250	0.30	0.0707	25,000	0.14
Middle of Scan	250	0.30	0.0707	25,000	0.14
Third Quarter of Scan	225	0.30	0.0707	25,000	0.13
Fourth Quarter of Scan	190	0.30	0.0707	25,000	0.11
End of Scan	150	0.30	0.0707	25,000	0.14
Scan #2:					
Start of Scan	50	0.30	0.0707	50,000	0.01
First Section of Scan	500	0.30	0.0707	50,000	0.14
First Quarter of Scan	800	0.30	0.0707	50,000	0.22
Second Quarter of Scan	1000	0.30	0.0707	50,000	0.28
Middle of Scan	1000	0.30	0.0707	50,000	0.28
Third Quarter of Scan	800	0.30	0.0707	50,000	0.22
Fourth Quarter of Scan	500	0.30	0.0707	50,000	0.14
End of Scan	300	0.30	0.0707	50,000	0.08
Scan #3:					
Start of Scan	50	0.30	0.0707	10,000	0.07
First Section of Scan	300	0.30	0.0707	10,000	0.42
First Quarter of Scan	500	0.30	0.0707	10,000	0.71
Second Quarter of Scan	1000	0.30	0.0707	10,000	1.41
Middle of Scan	1000	0.30	0.0707	10,000	1.41
Third Quarter of Scan	500	0.30	0.0707	10,000	0.71
Fourth Quarter of Scan	300	0.30	0.0707	10,000	0.42
End of Scan	50	0.30	0.0707	10,000	0.07

This table shows that the EDPUT varies from about 0.08 watts-sec/mm^3 to about 0.14 watts-sec/mm^3 for the first scan line which may produce local abrasion patterns. The EDPUT varies from about 0.01 watts-sec/mm^3 to about 0.28 watts-sec/mm^3 for the second scan line which may produce

somewhat different local abrasion patterns. The EDPUT varies from about 0.07 watts-sec/mm^3 to about 1.4 watts-sec/mm^3 for the third scan line. These latter, higher EDPUTs may be associated with more aggressive abrasion patterns including fraying. However, it should be seen that within a certain scanned line, the EDPUT value can vary 40% or so and yet within another line, the EDPUT may vary by over 1000%. Of course, the EDPUT values can vary as little as 25% or as much as 2000% to create different worn looks with different degrees of feathering.

In general, looking at these values, the EDPUT can increase by any desired amount. Moreover, while this system shows the EDPUT changing a few times within a scan, the EDPUT can change any number of times within a scan line. The EDPUT control is thus infinite and can vary a few percent to several thousand percent along each scanned line and from one scanned line to another.

The inventors observed that the cycle time to laze the abraded pattern on denim legs could be reduced to 8 seconds or less at a scan speed of 50,000 mm/sec by using higher power or duty cycle to maintain the intensity of the image.

Table II shows the variation in EDPUT along an individual scanned line for a different pattern.

TABLE II

EDPUT Calculations for Worn Pattern #2

	Power (watts)	Spot (mm)	Area (mm2)	Speed mm/sec	EDPUT watts-sec/mm3
Worn Pattern #2:					
Start of Scan	20	0.30	0.0707	10000	0.03
First Section of Scan	50	0.30	0.0707	10000	0.07
First Quarter of Scan	500	0.30	0.0707	10000	0.71
Second Quarter of Scan	500	0.30	0.0707	10000	0.71
Middle of Scan	500	0.30	0.0707	10000	0.71
Third Quarter of Scan	300	0.30	0.0707	10000	0.42
Fourth Quarter of Scan	150	0.30	0.0707	10000	0.21
End of Scan	20	0.30	0.0707	10000	0.03
Worn Pattern #2:					
Start of Scan	20	0.30	0.0707	20000	0.01
First Section of Scan	50	0.30	0.0707	20000	0.04
First Quarter of Scan	500	0.30	0.0707	20000	0.35
Second Quarter of Scan	500	0.30	0.0707	20000	0.35
Middle of Scan	500	0.30	0.0707	20000	0.35
Third Quarter of Scan	300	0.30	0.0707	20000	0.21
Fourth Quarter of Scan	150	0.30	0.0707	20000	0.11
End of Scan	20	0.30	0.0707	20000	0.01
Worn Pattern #2:					
Start of Scan	20	0.30	0.0707	50000	0.01
First Section of Scan	50	0.30	0.0707	50000	0.01
First Quarter of Scan	500	0.30	0.0707	50000	0.14
Second Quarter of Scan	500	0.30	0.0707	50000	0.14
Middle of Scan	500	0.30	0.0707	50000	0.14
Third Quarter of Scan	300	0.30	0.0707	50000	0.08
Fourth Quarter of Scan	150	0.30	0.0707	50000	0.04
End of Scan	20	0.30	0.0707	50000	0.01

The inventors realized that having the ability to vary EDPUT or power or duty cycle along each individual

scanned line provides advantages of superior control of the degree of feathering, and hence, the creation of an almost infinite variety of worn looks. Further, the EDPUT or power or duty cycle could change both along each individual scanned line as well as from scanned line to scanned line. EDPUT distributions such as shown in Tables III–IV could easily be achieved, along with almost any other EDPUT distributions that are specified.

Table III shows a non-uniform pattern with somewhat symmetrical shape along the center, whereas Table IV shows a non-uniform pattern with heavier applications of power in the lower left quadrant of the pattern. Hence, a greater variety of EDPUT patterns and thus worn looks can be created with these techniques.

TABLE III

EDPUT (watts-sec/mm3) Matrix for Worn Pattern #3

	X Position (mm)						
Y Position (mm)	0	5	10	15	20	25	30
0	0.05	0.1	0.2	0.3	0.1	0.08	0.02
10	0.1	0.3	0.5	0.5	0.2	0.1	0.03
20	0.2	0.4	0.7	0.7	0.3	0.2	0.1
30	0.4	0.6	0.7	0.7	0.4	0.3	0.1
40	0.4	0.5	0.7	0.7	0.3	0.3	0.1
50	0.3	0.4	0.7	0.6	0.2	0.1	0.05
60	0.2	0.3	0.4	0.5	0.1	0.1	0.03
70	0.1	0.2	0.3	0.4	0.05	0.05	0.02
80	0.05	0.1	0.2	0.3	0.05	0.03	0.01

TABLE IV

EDPUT (watts-sec/mm3) Matrix for Worn Pattern #4

	X Position (mm)						
Y Position (mm)	0	5	10	15	20	25	30
0	0.01	0.03	0.05	0.1	0.2	0.2	0.05
10	0.01	0.03	0.1	0.3	0.3	0.2	0.025
20	0.05	0.4	0.7	0.6	0.6	0.5	0.09
30	0.05	0.5	0.7	0.6	0.4	0.3	0.1
40	0.1	0.7	0.7	0.5	0.4	0.3	0.1
50	0.2	0.7	0.7	0.6	0.6	0.3	0.05
60	0.1	0.6	0.6	0.3	0.5	0.1	0.03
70	0.01	0.05	0.1	0.5	0.4	0.05	0.02

This revolutionary concept changes the "black and white" characteristic of the laser-scribed image to a new "gray-scale" characteristic. In the conventional laser marking of materials such as wood, plastic, metals, etc. the image is created at a constant EDPUT or power or duty cycle. In the case of laser marking denim, as described in the inventors earlier patents noted above, the image may be created by using a constant EDPUT on each line. Thus, one uniform color was formed after lazing and washing that was between indigo blue or black (for low EDPUT scribing) and white or gray (for high EDPUT scribing). However, the capability to continuously or discontinuously change the EDPUT allows the image to assume any shade (after washing) between indigo blue and white, along any section of the pattern. The shade is associated with the degree of abrasion or degree of wear. Hence, the ability to control the shade also allows control of the degree of abrasion and feathering.

Further, this new flexibility can thus allow for the creation of entirely new looks not possible by any other economic means. Worn looks, images, or entirely new looks with sections of continuously or discontinuously different shades between white and indigo blue can be created. The tech-

niques of continuously or discontinuously changing the EDPUT during laser scribing as described herein may have other applications in other material industries where lasers are used to mark materials such as wood, glass, plastic, rubber, fabric, steel and others.

As alluded to above, this system has the ability to more accurately assess worn looks. This is done by producing a control sequence which replicates the desired properties; in an on/off manner, continuous manner, discontinuous manner or in an analog manner. Any desired amount of control can be provided, limited only by the amount of EDPUT gradations produced by the system. The general EDPUT profile can still be specified ha graphically, but the precise point during the scribing of a line at which EDPUT will change can also be controlled. The EDPUT profile can include a percent of the highest power or duty cycle required. As an example, 50% values may be chosen for areas requiring light abrasion and 100% values can be chosen for areas requiring heavy abrasion.

A new technique which assists the apparel designer, is disclosed. This allows the operator to paint the desired shape or geometry of the pattern desired to be lazed on the denim to obtain the worn look on the computer screen. In addition, the designer specifies the degree of feathering or EDPUT or power or duty cycle profile. Again, this specification can simply be a percent of the maximum EDPUT, power or duty cycle.

Each level of effective applied power is associated with a color. Different sections of the pattern are painted with different color contents, where the color contents can be in full power, e.g., R,G,B levels or in gray scale levels. In one embodiment, the colors are associated with different levels of duty cycle control of the laser. The user draws on the computer screen, with the mouse, the desired shape of the pattern. Then the user can select different colors for different areas. This can use a point-and-shoot technique or selection from a menu or by right clicking on an area and selecting from a context menu. This click associates different sections of the pattern with different EDPUT/power/duty cycle levels. The actual power level or duty cycle associated with a given color may be set by a user, and may be modified for different materials.

A local abrasion effect can be produced using the user interface screen shown in FIG. **3**. FIG. **3** shows a graphical user interface which permits formation of a pattern, or a portion of a pattern which will form the basic design to be scribed on a garment. The actual pattern **300** is formed of a plurality of different sections. The outer section **305** defines the overall outer perimeter of the shape. Also within the sections are other perimeters shown as **310**, **315**, **320** and the like. The innermost shapes, such as **325**, are also shown. For shapes of this type, where the patterns define an oval pattern, many of the sections are concentric or semi-concentric. The sections can be defined by perimeters. Spaces between each two perimeters defines a section. Alternatively, each section can define a separate layer.

FIG. **3** also shows a plurality of operating parameters which can be set. This includes **330**, which sets the speed in inches per second and **332** which sets the laser scale factor in units per inch. The pattern scale factor **334** can also be set. The pattern dimension on the laser can be set. **338** indicates the drawing direction of the laser. **340** represents the color change. A boundary length is set in **342**. For some random or psuedo random processes, a random seed may be necessary. This random seed may be set. Typical editing controls, such as edit, save, preview, etc. are also shown.

350 represents the power profile. The colors **352** are on the left side, and the power profile in row **354** is associated with that color.

The system starts with the user selecting a section, either the outermost section or any of the more inner sections that are shown. Each of these sections can be set as having a specified power profile by associating a color from the color palette **352** with a section. The power profiles represent different laser intensities (EDPUT levels) and thus different degrees of wear. For example, the lighter outer sections such as **310** and **305** may be associated with a lower power duty cycle level. This creates a more lightly worn look. The darker sections of the pattern, such as the section **325**, may be associated with higher power duty cycles and represent a more heavier worn look. **325** might represent the part of the pattern that is drawn at the knee section. Different shades of gray (following washing of the garment) are shown in the areas between the two extremes. These areas represent colors of the pattern section that is between indigo blue and total white after the processing by the laser and washing of the garment. Each of these changes are displayed in color. The values can be saved in either grayscale or in full color and are stored as part of the pattern file, here shown as left.ppx.

The pattern file represents the power profile information for the specified pattern which is displayed and editable via the user interface.

Additional processing features are also used to give the pattern a more realistic look. A tool set, shown as **360**, can be selected to carry out these functions. A first tool which is described herein is the blend function. Blend can be carried out either pixel by pixel, or area by area. The specific area which is blended may be selectable. A blend computes an average color for each pixel or area by forming a weighted average of the color of the pixel or area and the color of neighboring pixels or areas, e.g. eight neighboring pixels or areas. The number of pixels forming the weights can be varied to achieve various outcomes.

Another tool, shown herein as the whisker tool, may aid in whisker generation. Users may set the length and angle of the whisker, and then automatically produce a whisker pattern which can be later edited by the user.

A "grain" tool is shown as part of **360** which produces a "grainy" look. The process for the grainy look gives each pixel, and its neighboring pixels, a color vote. The weight for each vote depends on how long the pixel has maintained the specified color. The terminology of "long" can refer to number of units of image in an area, for example. Again, while this system refers to colors, it should be understood that gray scales can also be used to view the separated sections. The sections can also be marked with other area delimiters, such as hatching, stipling or the like.

Another tool developed as part of this invention is a "blaster" tool. In a manner similar to that used by the "spray can" tool supplied with many computer drawing programs to "spray" a specific color, the blaster tool sprays "incremental intensity" onto the pattern. To continue with the analogy, every time a "droplet" from the spray can hits the drawing surface, the pixel or area that is hit adopts the color being sprayed. With the blaster tool, a pixel hit by a droplet of incremental intensity has its color level incremented to the next higher level. The effect of the tool produces an effect whose impact is dependent on an amount of time spent "blasting" a given region. A longer period of blasting causes more pixels to be colored with the effect and hence causes a greater impact.

The blaster tool can also be used in an intensity-removing mode. In this mode, pixels that are hit have their color level changed to the next lower intensity level.

Any pattern that is formed by natural wear can be accurately simulated through the use of the blaster tool.

Furthermore, this tool can be automated to draw certain common features automatically, for example, a curved line simulating a whisker, a pocket wear pattern and the ladder pattern that appears along the seams of worn jeans.

An "undo" function allows one or many functions to be reversed if the user does not like the effect. This can, for example, allow trying different sprays or other effects to test if a good result is obtained. If not, the operation is reversed. This system can produce a number of different effects. Communication of pattern parameters from the design computer to the laser control computer may be used to develop an efficient

system. Many formats have been developed for computer viewing, generation and transmission of graphic images. The format for these files may allow for a higher degree of image complexity (e.g., color) than required for the present purpose and therefore tend to provide more information and details than is needed for the present purposes.

A new file format has been developed called TBF (TechnoBlast Format) which communicates precisely those parameters required for converting the desired image into laser control commands.

The file in the "TBF" format may be a bit-mapped format of a matrix. Each value represents power level/duty cycle/EDPUT for each pixel in the image as well as other control values. This file format therefore includes an edput value, or at least a value indicative of the amount of effective energy to be applied to a pixel associated with each pixel or group of pixels that is handled as a unit.

Since the information can be stored on a pixel by pixel level, the writing laser can write in either the horizontal or the vertical direction, or in any other direction for that matter, based on the same information. The direction of writing can be selected by the drawing direction **38**. Assuming the writing is in the horizontal direction, the image is sliced into pixel-wide fragments. The slice **370** shows, in exaggerated form, one of these pixel wide fragments. It should be understood, however, that these pixels are not drawn to scale, and that in fact a real pixel could be of any desired size. Note that each pixel such as **372**, **374** may have a different EDPUT level associated with it. The EDPUT level is changed as the laser is scanning from pixel to pixel.

Many different kinds of looks can be produced using this system. The following describes only examples of these looks. It should be understood that other effects could easily be produced. Any of these looks can be obtained in any of the ways described herein, i.e., by authoring a special image intended for use in changing the color of textile fabric, or by scanning a real garment and using the results of the scan to form information to use in changing the color.

FIG. **4** shows a localized worn look which extends from somewhat below the waistband to the somewhat below the knee on each denim leg. The color of the worn look (after washing) varies from white or gray in the intense areas of the knee shown as **402** to black or blue indigo (less intense areas) along the top, bottom and side portions of the knee shown as **404**.

FIG. **5** shows an alternative look which is intended for use in the rear portion of the denim, e.g. in the seat area. Again, this portion is substantially oval shaped, but has some worn portions in the center **502** and less worn portions towards the edge **504**.

FIG. **6** shows a global worn look from the waistband to the end of the leg section where the color of the worn look (after washing) ranges from white or gray in the intense areas along the center and length of the pattern to indigo blue or black along the top, bottom and edges of the pattern.

FIG. **6** also shows the global worn look from the rear waistband to the end of the leg section, where the color of the worn look changes from white or gray in the intense areas of the pattern to indigo blue or black along the top, bottom and edges of the pattern.

FIGS. **7** and **8** show a whisker worn look with multiple lines from about ⅛ inch to about 2 inches in width by 1 to 14 inches in length. The color of the pattern changes from white or gray in the center of the pattern to indigo blue or black along the edges of the pattern. The whisker worn look can be along any area of the front and back of the denim jeans and may contain one or several rectangular sections.

A frayed look in the knee, rear seating area, along the bottom of the front and back leg section or any other area of the denim jean is shown in FIGS. **9–10**. The EDPUT is of sufficient magnitude to fray the denim so that individual threads are exposed or actual holes are provided in the denim.

This goes against the teaching in the above '444 patent, which teaches that punch through of the material is undesired. The specific "fraying" effect, provides enough EDPUT to intentionally cause damage to the material, however in a controllable and desired fashion.

A rectangular worn pattern of about 2 inches by 4 inches along the rear pocket of the denim is used to simulate the wear from a wallet in the back pocket, where the color of the pattern is white or gray along the periphery of the rectangle and indigo, blue or black in the center. FIG. **11** shows the TechnoBlast pattern image created for this type of look.

Any or all of these looks may be combined into a single image. The composite image may then be used to laze denim jeans. This may represent an additional benefit of this system. In previous systems, different processes were used to obtain different effects. For example, conventional sandblasting is used to produce local abrasion on front and back denim leg sections. Whiskers are made using a hand sanding operation where individual laborers produced the various whisker patterns. Frayed looks use hand sanding drills and the like. In this system, however, multiple effects can all be included within the same file. For example, FIG. **12** shows a composite file including a plurality of the effects shown above. An additional effect, in which the whiskers are shadowed, is shown as **1202** in FIG. **12**. Just above or below the whisker, a section is colored white. This indicates no lazing in that section such that after washing the area is denim blue. The whisker itself can be different colors to produce different feathering effects. This technique produces a shadowed effect for the whiskers considered quite desirable.

Previous systems of this type have used relatively low power lasers, e.g. from 25 to 100 watts, of the type intended for marking materials. Marking lasers have been used to form graphic images and text on plastic, wood, steel and glass. Another kind of laser, called the laser cutter, typically produces much higher powers, e.g. 250 to 2500 watts. One problem noted by the inventors is the cycle time for applying the worn pattern. When the low power lasers have been used, the cycle time may be on the order of minutes for each application.

The present application describes the use of a much higher power laser, e.g. a laser having a power level of 250 watts or higher, even more preferably 500 watts or higher, and most preferably 1000 watts or higher. For example, a cycle time for abrading denim jeans can be minutes with a 50 watt laser that is typically used for marking. A 500 watt laser can produce the same pattern in a few seconds. This 500 watt laser has typically only been used for cutting

operations, however. The expectation is that these higher power lasers would unintentionally damage the material. However, by adjusting the EDPUT, higher power lasers can safely be used.

As a specific example, the inventors were able to use the 500 watt lasers to laze abrasion patterns on the front and rear sections in 15 seconds as compared with two minutes for the sand blasting process. Using 2500 watt lasers for the application area is also contemplated, which will decrese the cycle time even further.

Additional developments were made during initial trials with high-powered lasers. One noted problem is that the desired level of power or duty cycle at the beginning of the scribing of a line can be higher than requested, here called an overshoot. The physical nature of the laser process requires that when changing from a lower level of power or duty cycle to a higher level of power or duty cycle, "inertia" of the power may cause the power or duty cycle to initially overshoot the desired higher power or duty cycle. This may cause an initial excess visible impact on the denim target. This effect may be strongest when the laser is actually turned from off (zero power) to on. The effect on denim becomes much more evident when higher power lasers are used, e.g. 500 watts or higher.

To overcome this problem, a boundary solution is used. The desired pattern is given a "boundary" area. The laser power is set to a level x that is as high as possible without causing any visible effect on the denim or other garment material. The laser output is brought to a position outside the boundary. Since the laser is at the power level x, this causes no visible change. When the laser beam enters the region of desired visible impact, the effective power level is increased. The effective power level is increased less at that time, since the increase is from x to the desired level, rather than from 0 to the desired level. Overshoot from initial turn on may be reduced in this way.

Another important feature noted by the present application is based on the interference based on the pattern/lines that are scribed by the laser, and the direction of the materials stitch lines. Certain undesirable "interference patterns" may be produced by the interaction between the laser writing properties, the frequency of the laser and the directional properties of the material. These directional properties can include any aspect of the material that is asymmetric—and specifically can include cut, fill and twill of the denim fabric. A rotation of the fabric or the scribing direction may change this effect. Orienting the material such that the scan line makes a 90 degree angle with the cut, fill or twill minimizes the effect, when it is desired to minimize that effect. However, some of the interference patterns themselves produced quite interesting looks for denim jeans, and may be desirable. Hence, one aspect of this system includes taking into account the effects of the interaction between the laser scanning and the directional properties of the material.

Hence, another parameter of this system requires the directional pattern of the material to be placed in a specified orientation. This can also be controlled by changing the drawing direction using control **338**. One other aspect uses a camera vision system pointed to face the material and to automatically detect the directional properties of the material. Those properties are then input into the computer, and used as one parameter of operation.

As mentioned previously, it is highly desirable to avoid an artificial or contrived look when attempting to simulate natural wear. It is therefore useful to minimize the opportunity for the human eye to perceive any regularity in the pattern produced by the laser. One approach to achieving this is to allow the user to specify the power levels in the design, but to cause the precise point at which power changes between two adjacent levels to be determined at random. This feature may not always be desirable. Hence, randomization of power level change is a user selectable option.

The higher power lasers can operate faster, and therefore benefit from more automated processes. The conveyer system shown in FIG. **1** provides the denim jeans **100** over some form **102**. The denim jeans are introduced to the laser in a horizontal direction. The laser then scribes the worn look, after which a second pair of jeans shown as **110** are maintained behind it and also introduced for subsequent processing. After processing a batch of jeans in this manner, they can be removed from the form and reversed to either the same or different laser to scribe the worn look on the rear. FIG. **1** also shows an in-line material processing system, including an inline-laundry device **120**, e.g, a system that applies shampoo with a brush, and a removal system, such as a wet vac **130**. This can use components from commercially available rug cleaning systems, e.g. a rug doctors or similar shampoo/vacuum combination can produce a desired effect with an in line system.

FIG. **1** shows a straight path conveyer system. However, a carousel type conveyor is contemplated.

An alternative system is shown in FIG. **13**. The jeans **1300** are located on a form shown as **1302**. The form holds the jeans in some way e.g. using clips on the inside shown as **1304**, **1306**. These clips hold the denim jeans in place on the form. Each of the forms also include a rotation rod **1308** connected to a rotator **1310**. The jeans are conveyed along the conveyer **1312**, which includes at least two of these rotators, the second one being shown as **1315**. At a first location, the jeans come into contact with a first laser **1320**. This laser produces the worn look on the front of the jeans shown as side **1**. After so doing, the rotator **1308** is lifted up and causes the jeans to be flipped to side **2**. Subsequently, side **2** comes into contact with the second laser **1330** which scribes the rear worn look. The jeans are removed from the form after processing, and a new pair of unprocessed jeans applied to the form. While this system describes using two lasers, it should be understood that a single laser could be used, i.e. by scribing the front side of one or multiple pair of jeans, and later flipping all the jeans and scribing the other side. An automated system can detect whether the front or back is being presented, e.g. by imaging the garment to look for the label or bar code on the jeans. A camera vision system can key in on a specific area of the jean such as the waistband each time and simply adjust the laser scan to insure proper placement of the image on the denim each time.

FIG. **14** shows yet another system. The jeans are held from their sides by clipping on a clip area to a specified location, e.g. the inside of the pocket where minimal denim processing will take place. Other clip areas are also possible. The materials processing system carries the denim by the clip areas, e.g. by a wire which is constantly moving.

Alternately, a form of the type shown in FIG. **13** can be used as free standing conveyer system. In this embodiment, dual lasers are used, with one on the top scribing the worn look on the top surface **1400** of the jeans and the other laser **1420** on the bottom, scribing the worn look on the bottom surface of the jeans **1405**. Any free standing conveyer system can be used for this. For example, this may also be done with the garment suspended on a hanging system in the vertical direction. Different form shapes are also possible.

Different type of worn looks may be obtained depending upon the type of form that is used. For example, typical

metal forms such as used in the dry cleaning industry produce a worn look that is similar to that obtained from sandblasting, since the garment is relatively flat as the laser scribes the worn look on the garment. However, using an inflatable balloon type form, such as used in some denim finishing plants, produces a somewhat different worn look. The balloon is inflated inside the denim pant leg, causing the fibers to be spread. The jean wraps around the form in a concave fashion during scribing.

The inventors noted that this invention produced benefits in the production of denim jeans with whisker patterns to simulate the creases along the thigh and knee section. Denim manufacturers have tried numerous methods to create the desired whisker patterns. Many have noted that only the hand sanding process was really acceptable to create the authentic worn look for the whiskers. This process may be labor intensive and the quality of the whisker pattern is a function of the skill of the laborer who sands the whiskers on the denim. Considerable variability exists from one laborer to another, as would be expected. Some laborers apply too much pressure and some too little pressure such that the quality of the end product is quite variable.

However, the inventors noted that using the new technique of changing the EDPUT along the individual scribed lines, any desired whisker pattern could be exactly replicated. Further, a typical whisker pattern could be applied to the denim jeans with this invention in a few seconds, compared to several minutes with the hand sanding operation. The quality of the whisker pattern produced from this system is consistent from one denim jean to the other because of the consistency of the laser scribing process. Hence, the yield would be expected to be significantly greater with this invention compared with the hand sanding operation.

Although only a few embodiments are disclosed, other modifications are possible and are intended to be encompassed within the following claims. For example, other marking elements, that is other marking elements besides a laser, are contemplated.

What is claimed is:

1. A method comprising:

storing information about effective applied power levels for a plurality of scan lines of a laser element, at least a plurality of said scan lines having levels of effective applied power which change within a single scan line; and

using a laser to process a material by controlling scan lines of the laser to have a controlled energy density per unit time which depends on said effective applied power levels.

2. A method as in claim **1** wherein at least a plurality of said effective applied power levels are values which do not undesirably damage a material.

3. A method as in claim **2** wherein at least a plurality of said effective applied power levels are values which intentionally cause a hole in the material to cause fraying.

4. A method as in claim **2** wherein said material is a denim garment.

5. A method as in claim **1** wherein said information is indicative of a simulated abrasion effect to create a worn look.

6. A method as in claim **1** wherein said information is indicative of simulated whisker effect.

7. A method as in claim **1** wherein at least part of said information is indicative of a simulated fraying effect.

8. A method as in claim **1** wherein said laser has an output power of 500 watts or greater.

9. A method as in claim **1** wherein said laser is one which has an output power of 1000 watts or greater.

10. A method as in claim **1** wherein said information represents an oval shaped pattern.

11. A method as in claim **1** wherein said control of effective applied power levels is carried out by control of duty cycle of said laser thereby controlling an effect of amount of power delivered by the laser in a pulsed manner.

12. A method as in claim **11** wherein said control of duty cycle comprises turning a laser on and off at specified rate.

13. A method as in claim **12** wherein said specified rate is fast relative to the movement of the laser.

14. A method as in claim **11** wherein said control of duty cycle comprises selectively blocking and unblocking an output of the laser to thereby control an effective amount of power delivered by the laser.

15. A method as in claim **1** further comprising changing the EDPUT by changing a speed of movement of the laser.

16. A method as in claim **1** wherein said change of effective applied power levels comprises changing an output size of a laser beam that is output from the laser.

17. A method as in claim **1** further comprising feathering an edge of the pattern by changing a power level of the image at said edge to form a more gradual change of effect at said edge.

18. A method as in claim **1**, wherein said information is in a specified format, which includes an indication of an area and an indication of an effective applied power level to be applied to said area.

19. A method as in claim **1**, wherein said effective applied energy is one of an energy density per unit time, power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser.

20. An apparatus, comprising:

a computer controlled laser, having an output which impinges on a surface to be modified by said laser and which is controlled according to a computer file, said computer controlled laser producing said output beam having a controlled effective applied power level of application to the area, according to said computer file, wherein said computer file includes at least a plurality of scan lines in which said effective applied power level changes within a single scan line at least three times to at least three different values.

21. An apparatus as in claim **20** wherein said laser has a power output of 500 watts or greater.

22. An apparatus as in claim **20** wherein said laser has a power output of 1000 watts or greater.

23. An apparatus as in claim **20** wherein said effective applied power level is selected for a specific textile material to be lazed, and at least one of said effective applied power levels in said computer file changes the look of the textile material without undesirably burning, punching through or otherwise harming the textile material.

24. An apparatus as in claim **23** where at least one of the effective applied power levels in said computer file does cause burn through of the material to expose fibers in the material.

25. An apparatus as in claim **23** further comprising an in-line shampooing element, which provides a shampooing operation and a shampoo removal operation to a garment which has been lased by the laser.

26. An apparatus as in claim **20** wherein an effective applied power level of the laser is changed by turning on and off the laser at a specified duty cycle.

27. An apparatus as in claim **20** further comprising an adjustable shutter which modulates an output of the laser,

and a control element which turns on and off said shutter, based on said computer file, to adjust said effective applied power level.

28. An apparatus as in claim **27** wherein said shutter is a piezoelectric element.

29. An apparatus as in claim **27** wherein said shutter is a mechanical shutter.

30. An apparatus as in claim **20** wherein said effective applied power level changes to at least five different values in at least a plurality of scan lines of said laser.

31. An apparatus as in claim **20** wherein said effective applied power level changes between a lowest value and a highest value, wherein said highest value is at least 125% of said lowest value.

32. An apparatus as in claim **20** wherein said effective applied power level changes between a lowest value and a highest value, wherein said highest value is at least twice said lowest value.

33. An apparatus as in claim **20** wherein said file represents a pattern which includes a feathering portion at an edge of the pattern where a change in effective applied power level is made gradual to gradually change an effect thereof.

34. An apparatus as in claim **20** further comprising a control console, having a user interface, said user interface graphically showing a pattern which is to be lased, said pattern including differently highlighted areas for different effective applied power levels.

35. An apparatus as in claim **34** wherein said differently highlighted areas comprise different colors.

36. An apparatus as in claim **35** further comprising a look up table which stores a relationship between an effect to a material, and a duty cycle of operation of the laser to provide said effect.

37. An apparatus as in claim **35** further comprising an editing tool which enables editing said pattern.

38. An apparatus as in claim **34** wherein said differently highlighted areas comprise different gray scales.

39. An apparatus as in claim **20**, wherein said computer file includes a plurality of information parts, each information part associated with a specific area on an image representing a garment to be altered, and each information part including information indicating effective applied power level information for a laser.

40. An apparatus as in claim **20** wherein said file stores a pattern of a simulated worn pattern.

41. An apparatus as in claim **20** wherein said file represents a pattern which stores a simulated whisker pattern.

42. An apparatus as in claim **20** wherein said file represents a pattern which stores a pattern with a hole through the denim of a type which exposes fibers of the denim.

43. An apparatus as in claim **20**, wherein said effective applied energy is one of an energy density per unit time, power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser.

44. An apparatus comprising:

a controllable laser, which is controllable by a computer file, to produce an output on a desired area, said laser having a maximum output power which is 500 watts or greater; and

said computer file storing control information which adjusts a duty cycle of an output of said laser to control an effective applied energy applied to said area to a desired amount and providing said information for a desired energy density per unit time to said controllable laser for said area.

45. An apparatus as in claim **44** wherein said laser is controlled to scan in lines, and wherein a plurality of said lines have different effective applied area at one area than in another area.

46. An apparatus as in claim **45** wherein said effective applied energy changes to at least three different values within a single scan line.

47. An apparatus as in claim **44** wherein at least some of said effective applied energies is set to a specific value relative to a material in said area, which changes the abrasion or color of said material without undesirably damaging the material.

48. An apparatus as in claim **44** where at least part of said effective applied energies provides a desired punch through effect in said material.

49. An apparatus as in claim **44** further comprising a terminal, which provides an image of a simulated pattern to be applied to the material, said image having differently indiciaed areas to represent different effective applied energies.

50. An apparatus as in claim **49** wherein said indiciaed areas comprise differently colored areas.

51. An apparatus as in claim **49** wherein said indiciaed areas comprise different grayscales.

52. An apparatus as in claim **49** wherein the simulated pattern has a plurality of concentric oval areas.

53. An apparatus as in claim **44** further comprising a duty cycle controller comprising and on off control for the laser.

54. An apparatus as in claim **44** further comprising a duty cycle controller comprising a shutter, selectively opened and closed at an output of the laser.

55. An apparatus as in claim **44**, wherein said effective applied energy is one of an energy density per unit time, power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser.

56. A method, comprising:

defining a desired pattern of color alterations to be formed to a garment by selecting a plurality of areas on a display, defining a color that is associated with each of a plurality of abrasion levels, selecting a color to associate with each of the plurality of areas to thereby associate a level of abrasion with each of the plurality of areas; and

storing a computer file indicative of said selecting.

57. A method as in claim **56** further comprising enabling said display to be edited, to change color and or shape.

58. A method as in claim **57** wherein said computer file specifies information for use in forming control data for a laser to scribe lines on a desired garment, wherein at least a plurality of said lines specify an energy density per unit time which changes within a single scan line.

59. A method as in claim **58** wherein at least a plurality of lines have an energy density per unit time which has at least three values within the specified line.

60. A method as in claim **59** wherein a highest of said three values is at least 1.25 times as high as a lowest of said three values.

61. A method as in claim **57** wherein said editing comprises applying an abrasion using a spray tool.

62. A method as in claim **57** wherein said editing comprises decreasing a resolution of said image.

63. A method as in claim **56** further comprising storing, in a memory, a relationship between each color and an amount of effective applied energy representing the color.

64. A method as in claim **57** further comprising using a laser and controlling the laser to control an effective applied power applied to an area by controlling a duty cycle of the laser.

65. A method as in claim **64** wherein said duty cycle is controlled by selectively blocking and unblocking an output of said laser.

66. A method as in claim **64** wherein said duty cycle is controlled by turning on and off the laser.

67. A method of processing a garment, comprising:

defining a desired pattern to be formed on the garment and producing a computer file indicative thereof;

using said computer file with a laser having a maximum output power of 500 watts or greater, to scribe the desired pattern on said garment; and

using said laser for thirty seconds or less to form said entire pattern.

68. A method as in claim **67** further comprising controlling an effective output power of said laser by controlling a duty cycle of operation thereof.

69. A method of forming a pattern on a garment comprising:

determining a pattern to be formed on a garment;

determining an effect that a directional characteristic of the material will have on the pattern to be formed; and

specifying both said pattern and said directional characteristic.

70. A method as in claim **69**, wherein said specifying includes forming a computer file indicative of areas, and effective power output levels associated with each said area.

71. A method as in claim **70**, further comprising using said computer file to control a controllable laser, to form an effect on a material.

72. A method of processing a garment, comprising:

obtaining a first garment which has a desired look to be replicated;

determining color levels of different areas of a plurality of different areas of said first garment;

determining, from said color levels, an amount of effective applied energy of laser energy which will need to be applied to said each of said area to replicate said color level; and

forming a computer file which has a plurality of area representations, each area representation associated with a power representation representing said amount of laser power which needs to be applied to each of said areas to replicate said different areas of said first garment.

73. A method as in claim **72** further comprising using said computer file to control a laser to mark a second garment in a way that replicates a pattern of the colors on the first garment.

74. A method as in claim **73** wherein said laser marks said second garment by scribing a plurality of lines on said second garment using said computer file.

75. An apparatus as in claim **74** wherein at least a plurality of said lines define an effective applied energy which varies within each of a plurality of single scanned lines.

76. A method as in claim **72** further comprising storing information in a look up table, and using said information to determine said effective applied energy for each of said areas.

77. A method as in claim **72** further comprising displaying a graphical image indicative of said computer file to a user and allowing said user to edit said graphical image to thereby edit said computer file.

78. A method comprising:

defining a pattern to be formed on a textile material, which pattern represents different degrees of abrasion of said textile material at different locations, and which represents at least first areas which have no abrasion, and producing a computer readable file indicative of said pattern; and

controlling a laser to form said pattern by first controlling said laser according to said file to produce an effective output power in said first areas which is greater than zero, but is less than a threshold beyond which a visible change will be made to said textile material, and to increase the effective output power at a boundary between said first areas, and other areas outside said first areas.

79. A method comprising:

defining a pattern to be formed on a textile material, which pattern represents a plurality of sections, each section having a separately controllable amount of degree of change, said different degrees of change including at least a plurality of different levels of change;

randomizing a precise point at which the degree of change actually is bounded between two adjacent levels; and

forming a computer-readable file indicating said pattern and information about said degree of change, including the randomized boundary.

80. A method as in claim **79**, wherein said degree of change information is information about an effective applied power level for a laser, and said file includes said information associated with location information.

81. A method as in claim **80**, further comprising using a laser to apply said effective applied power levels at specified locations represented by said location information.

82. A method as in claim **80**, wherein said effective applied energy is one of an energy density per unit time, power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser.

83. A method comprising:

defining a pattern to be formed on a textile material, which pattern has different colors representing different degrees of change of said textile material at different locations, said different degrees of change including at least a plurality of different levels of change, each different level of change associated with an effective applied energy to be applied to said location;

defining a tool which allows a spray of incremental intensity onto the pattern, by defining a droplet size and trajectory, determining a location that is hit by a droplet; adjusting a color level of said location based on said hit so that said effective applied energy is adjusted by said hitting.

84. A method as in claim **83**, wherein said colors are one of full colors or gray scales.

85. A method as in claim **83**, wherein said locations are pixels.

86. A method as in claim **83**, wherein said adjusting comprises incrementing a color level of said location to a next higher color level.

87. A method as in claim **83**, wherein said effective applied energy is one of an energy density per unit time, a duty cycle of an output of a laser, a speed of movement of a laser, a distance of a laser or a number of passes of a laser.

88. A method as in claim **83**, wherein said adjusting comprises incrementing a color level of said location to a next lower color level.

89. A method of providing a variable effect to a material, comprising:

changing an effective applied power from a laser to a material by making multiple passes of laser scans along specific segments of the pattern, each of said passes being carried out at constant power, speed and laser distance, but the combination of said multiple scans providing a varied effective applied power at said material.

90. A method as in claim **89**, wherein said changing comprises defining a file having different levels of effective applied energy, and using said file to control a number of said passes which are carried out in each of a plurality of areas.

91. A method as in claim **90**, wherein said areas are pixels.

92. A method comprising:

authoring a special image intended for use in changing the color of textile fabric, which has differently colored areas representing different levels of change of color to said textile fabric; and

using said image to form a file that controls a laser to carry out said changing of color of said textile fabric.

93. A method as in claim **92**, wherein said file includes levels of effective applied energy associated with said levels of change of color.

94. A method as in claim **93**, wherein said effective applied energy is one of an energy density per unit time, power level of a laser, a duty cycle of an output of a laser, a speed of movement of a laser, or a distance of a laser.

95. A method as in claim **92**, wherein said file includes a separate effective applied energy value for each pixel of the image.

* * * * *

EXHIBIT 4

United States Patent [19]

Bricot

[11] **Patent Number: 4,901,089**

[45] **Date of Patent: Feb. 13, 1990**

[54] **METHOD AND DEVICES FOR THE RECORDING OF PICTURES BY LASER**

[75] Inventor: **Claude Bricot,** Villejuif, France

[73] Assignee: **Thomson-CSF,** Puteaux, France

[21] Appl. No.: **286,513**

[22] Filed: **Dec. 19, 1988**

[51] **Int. Cl.**[4] **G11B 7/00;** G01D 9/42

[52] **U.S. Cl.** .... **346/76 L;** 346/108; 369/44; 369/100

[58] **Field of Search** .... 346/76 L, 108, 107 R, 346/160; 369/100, 106, 121, 44

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,584,612 4/1986 Ono .

4,727,381 2/1988 Bille 346/108

FOREIGN PATENT DOCUMENTS

56-113494 9/1981 Japan .

59-31190 2/1984 Japan .

60-052390 3/1985 Japan .

OTHER PUBLICATIONS

IBM Technical Disclosure Bulletin, vol. 24, No. 2, Jul. 1981, "Multi-Color Recording Medium".

Primary Examiner—B. A. Reynolds
Assistant Examiner—Scott A. Rogers
Attorney, Agent, or Firm—Roland Plottel

[57] **ABSTRACT**

A method for recording pictures wherein a material to be scanned by a laser beam comprises a first layer laid on a substrate to form a picture zone and a reading zone and a second layer laid on the picture zone only which is capable of absorbing laser radiation. The laser beam is capable of double relative motion with respect to the above material with a first fast motion along a first axis and with a second motion, slow in comparison with the first motion, along a second axis which, for example, may be perpendicular to the first axis. The power of the laser beam is modulated as a function of the information to be recorded in synchronism with the above mentioned first motion. The laser beam is guided by information from the reading zone which describes the picture zone where the picture has to be formed in strips parallel to the first axis by the destruction or non-destruction of the absorbent layer thereon, thus causing the first layer to be revealed or not revealed depending on the power of the laser beam and, therefore, on the information to be recorded. After recording the reading zone is removed.

6 Claims, 3 Drawing Sheets

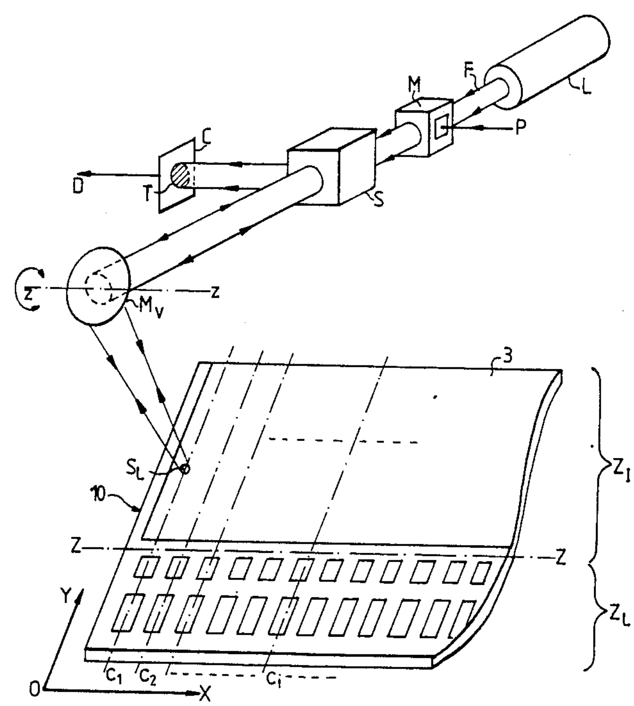


FIG.1a

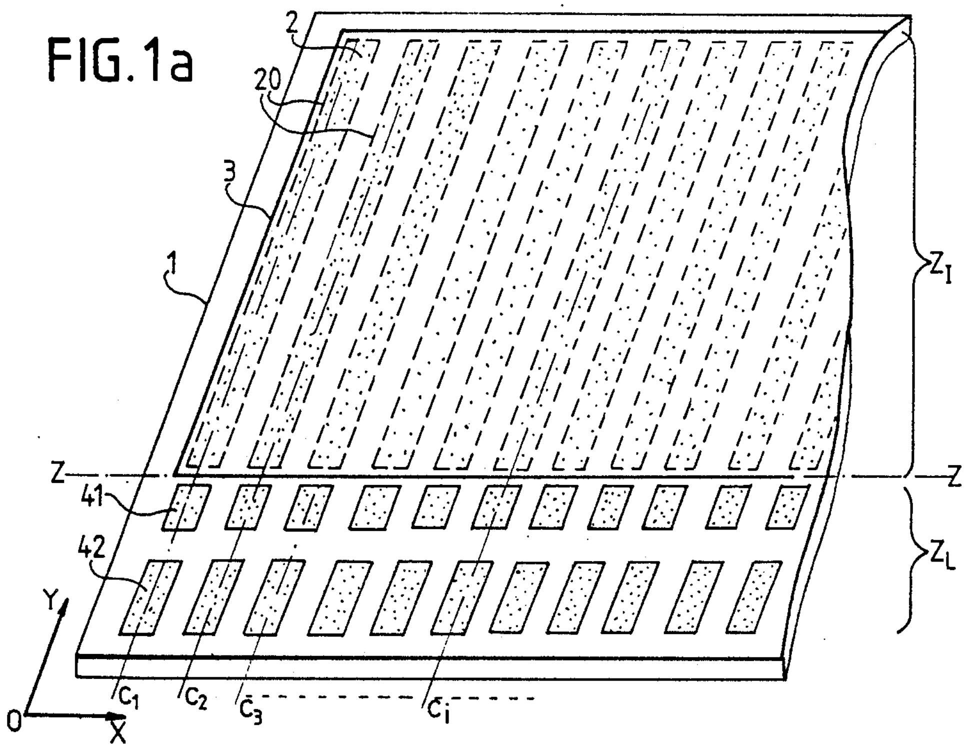
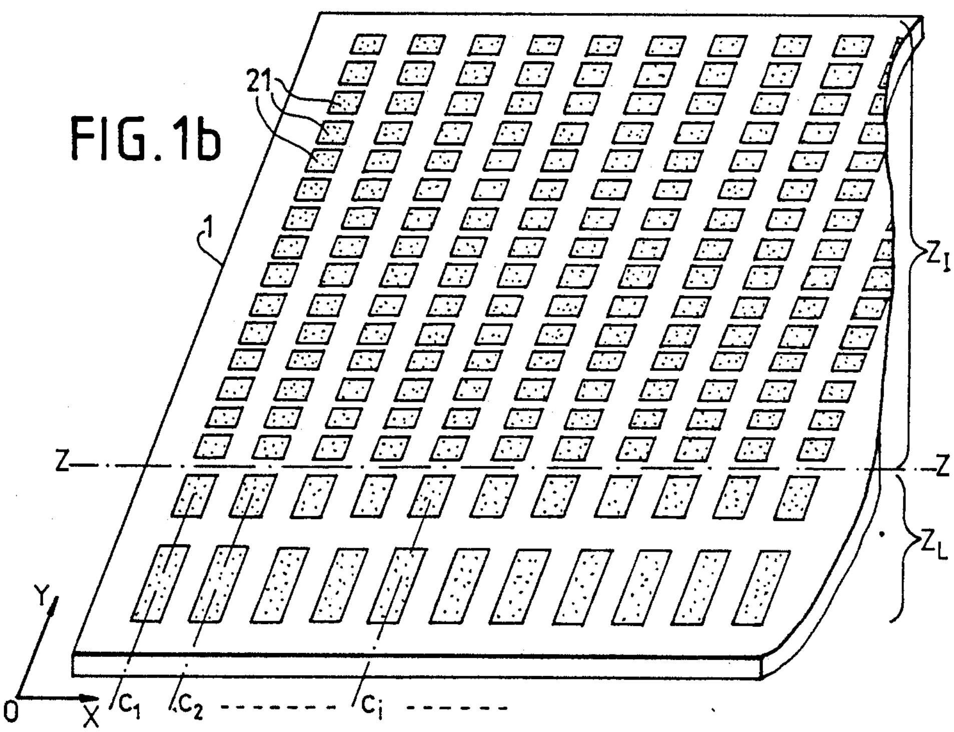


FIG.1b



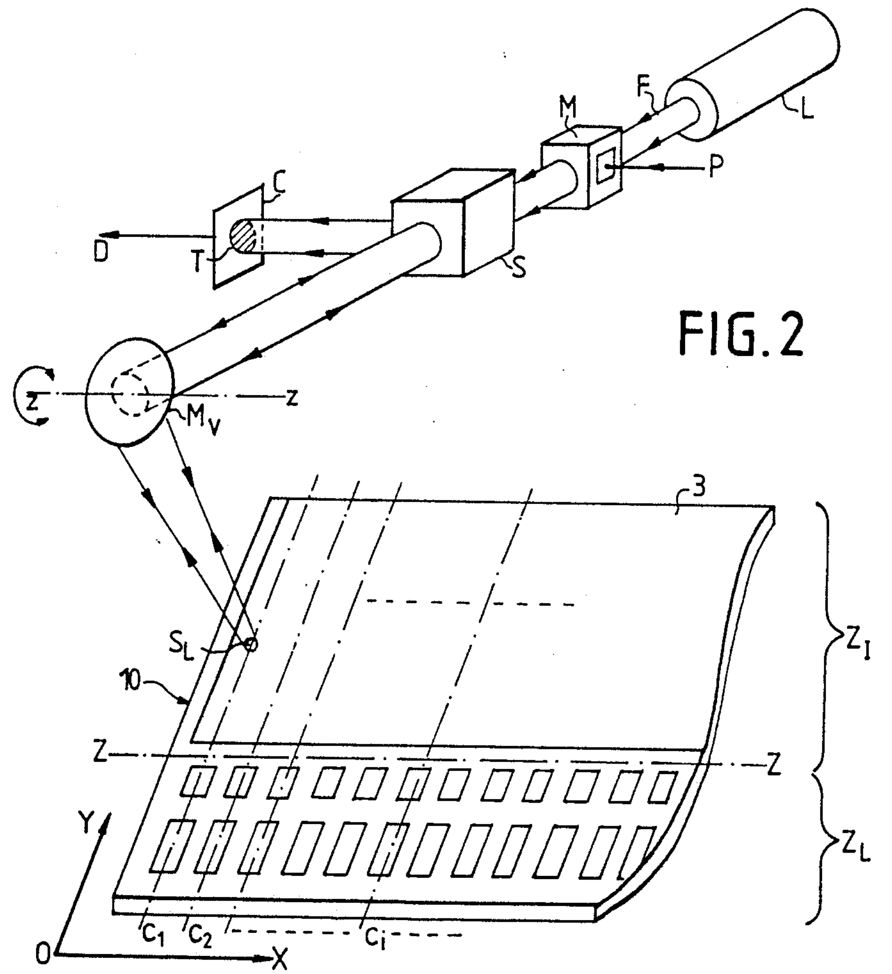


FIG. 2

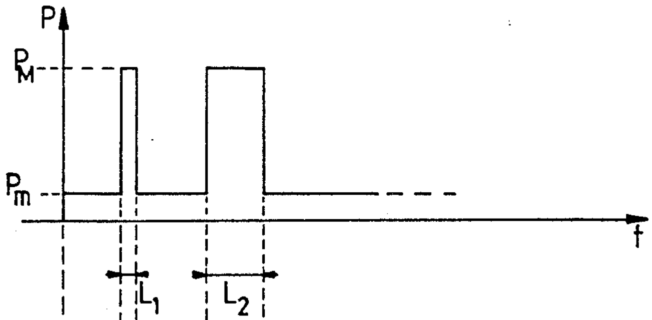


FIG. 3a

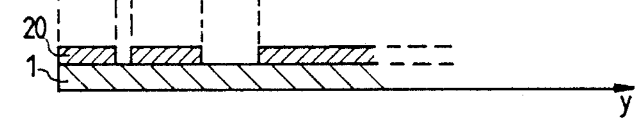


FIG. 3b

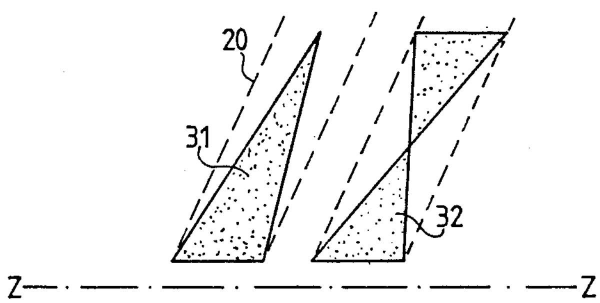


FIG. 3c

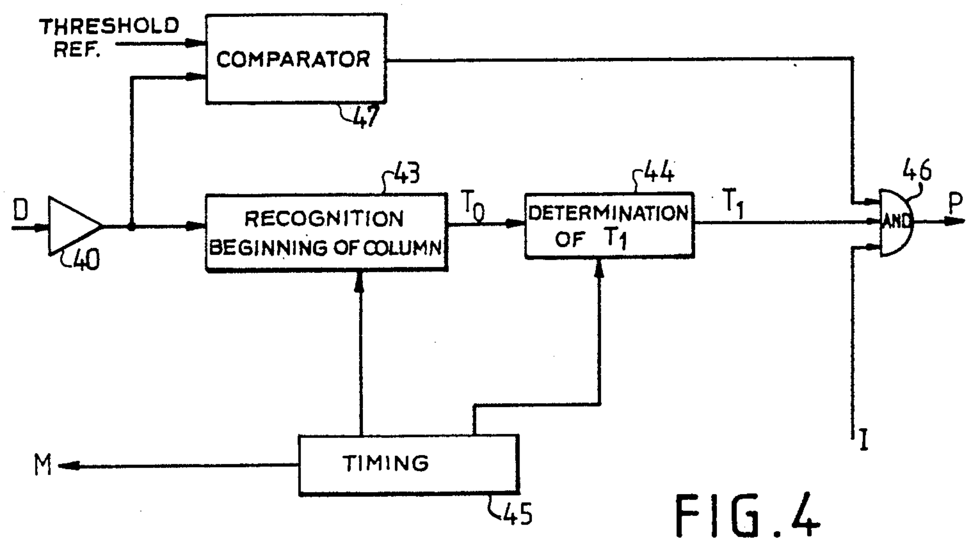


FIG. 4

METHOD AND DEVICES FOR THE RECORDING OF PICTURES BY LASER

BACKGROUND OF THE INVENTION

1. Field of the Invention

An object of the present invention is a method to record images or pictures by laser as well as means to implement it.

In the present description, the term "picture" refers to graphic representations as well as to printed text and photographs, etc.

In certain applications, a picture has to be formed on a medium which is hard to falsify or counterfeit.

2. Description of the Prior Art

Various methods are known for this purpose. Among them, we might cite the printing of blank bills where a chemical transfer process is used. Various special devices are used to make this method hard to falsify but, for certain uses, the method does not make it difficult enough to counterfeit.

Other methods, such as those used to manufacture digital optical disks, use a mechanism for the ablation of a layer selected to absorb incident radiation. Once the absorbent layer is removed by radiation, it lets the medium appear at specific places, thus forming an picture. These methods, however, do not give good "rendering", namely quality (picture definition, contrast, etc.) similar to that of pictures made by printing.

An object of the present invention is therefore, the making of a picture with rendering quality comparable to that of a printed picture which is as difficult as possible to falsify and as difficult as possible to counterfeit, a method of this type being applied notably in the making of top security documents such as identity papers for example.

SUMMARY OF THE INVENTION

The method according to the invention enables these goals to be met through the use of:

A first layer of material, laid on a substrate and forming two zones, a picture zone and a reading zone. The first layer is coated on the picture zone with a second layer capable of absorbing laser radiation.

A laser beam capable of a double relative motion with respect to the above material, i.e.:

* a first fast motion along a first axis;
* a second motion, slow in comparison with the first motion, along a second axis which, for example, may be perpendicular to the first axis;

Means to modulate the power of the laser beam as a function of the information to be recorded in synchronism with the above-mentioned first motion. The laser beam is guided by means of the reading zone and describes the picture zone where the picture has to be formed in strips parallel to the first axis, by the destruction or non-destruction of the absorbent layer thereon, thus causing the first layer to be revealed or not revealed, depending on the power of the beam and, therefore, on the information to be recorded. After recording, the reading zone is removed.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, special features and results of the invention will emerge from the following description, illustrated by the appended figures, of which:

FIGS. 1*a* and 1*b* show different embodiments of the medium of the picture;

FIG. 2 shows an embodiment of the optical means for recording the picture;

FIGS. 3*a*, 3*b* and 3*c*, are explanatory drawings of the working of the device according to the invention;

FIG. 4 shows an embodiment of the electronic means for controlling the optical means of FIG. 2, to implement the method according to the invention.

In these differents figures, the same references are repeated for the same elements.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1*a* shows a first embodiment of the medium of the picture according to the invention.

This figure therefore shows a substrate **1**, for example, made of paper, cardboard or plastic, on which two zones are defined: a picture zone Z_1 and a reading zone Z_L separated by an axis ZZ, parallel to the axis OX of an orthonormal reference OXY. In the picture zone Z_1, a first material **2** is deposited in strips **20** parallel to the axis OY, thus forming columns marked C_1, C_2, C_3 . . . C_i . . . This material **2** is, for example, an ink deposited by a photoengraving, smooth cutting, offset or other type of method.

In the picture zone Z_1, there is deposited a layer **3** of a second material chosen to absorb a pre-defined radiation such as a laser radiation. Preferably, this material **3** is characterized by a low melting temperature. However, it may be preferable, for certain applications, that this temperature is not too low, for example about 200° C., to remain greater than the temperatures at which the media plastifications are usually made. The layer **3** is, for example, organic or metallic. It may have a small thickness, its aborption being determined, for a given radiation, by its composition and thickness. For example, a telluride layer of about 200 Å would be appropriate.

In that part of the medium corresponding to the reading zone Z_L, strips of the first material (**2**) have also been deposited along the columns C_1, C_2 . . . C_1. These strips may or may not be continuous: for example, they are shown in FIG. 1a in two patterns marked **41** and **42**, also aligned in the columns C. It must be noted that the material forming the columns or patterns of the reading zone Z_L may be different from the material **2**. For the clarity of the figure, the surfaces of the strips **20** and the patterns **41** and **42** have been shown with dashes.

FIG. 1*b* shows an embodiment alternative to that of the previous figure. The embodiment shown in FIG. 1b is different in that the strips **20** of the picture zone Z_1 are now made in discrete form by means of microsurfaces **21**, aligned in columns C as above. For example, microsurfaces may be 20 μm square.

To simplify, the figure, the layer **3** of absorbent material has not been shown.

FIG. **2** shows an embodiment of the means for the optical recording of the picture in the above medium.

This figure shows, as an example, and under the general reference **10**, the device described with reference FIG. **1**, comprising the reading zone Z_L and the picture zone Z_I, *the latter being coated with the absorbent material* 3.

The recording device has a laser L emitting a light beam F towards the modulator M. This modulator M is controlled by a signal P. This control enables the power of the laser L to be modulated according to the informa-

tion to be recorded on the device **10**. In leaving the modulator M, the light energy is directed towards a vibrating mirror M_v, through separation means S. The mirror M can oscillate on an axis zz, parallel to the axis OX. The mirror M sends on the laser beam F towards the device **10**, on which it forms a spot S_L.

If necessary, the device may further have means (not shown) to focus the beam F on the device **10**.

Depending on the power of the beam, as controlled by the above signal P, the device works in one of the two following ways:

the first mode of operation corresponds to a case where the luminous power is low, for example between 1 mW and 3 mW;

the second mode of operation corresponds to high luminous power, for example a few tens of milliwatts, enabling the local ablation of the layer **3** and thus revealing the material **2**.

The zones in which the material **2** is revealed together form the picture sought.

Controlling the motion of the mirror M around the axis zz enables the spot S_L of the laser beam to describe a column C of the picture zone Z_I. Besides, the device **10** is moved along the axis OX by a translational motion with respect to the optical device, so as to enable to the laser beam to go from one column to the next one. This motion may be either discontinuous, limited to the time available between the spot scan motions along the axis OY, or continuous and slow with respect to the scan motion along OY, so as to enable writing in parallel columns.

As a result, by means of the modulator (M) control signal (P), a picture is recorded on the zone Z_I, the quality of which depends on the parameters chosen, notably for the conrol of the beam F power and the spot S_L scan speeds.

In an alternative embodiment, the substrate **1** has a color different from that of the strips **20** or the microsurfaces **21**, in order to make any falsification more difficult: for an attempt at falsification then entails a high probability of revealing the medium instead of the material **2**.

Various alternatives are possile for the control of the laser beam, and are illustrated by FIGS. **3**a to **3**c.

The light pulses may be of constant width according to a constant frequency, and the recording is then of the binary type.

In one alternative embodiment, the light pulses may be of variable width so as to enable the appearance of a pattern with a variable size. This is what is shown in FIG. **3**a.

In this FIG. **3**a, the power P of the laser beam F has been shown as a function of time. The power P changes between a minimum level P_m and a maximum level P_M with a variable pulse width (L_1, L_2. . .).

FIG. **3**b shows a partial section of the device **10**, made along a column when the latter receives the modulated laser beam as shown in FIG. **3**a.

In this section, the substrate **1** is shown partially covered by a strip **20**. For, this strip **20** remains when the power of the laser is at the minimum level P_m and is, on the contrary, eliminated by the laser beam on widths corresponding to the pulse widths L_1 and L_2.

If the columns are formed by microsurfaces, as described with reference to FIG. **1**b, the pulses should be synchronized with these microsurfaces.

In an alternative embodiment, the power of the laser beam no longer changes in a binary form between two levels P_m and P_M as shown in FIG. **3**a, but changes variably between these two levels. This makes it possible to destroy the absorbent layer **3** more extensively or less extensively and thus reveal patterns which are, for example, substantially triangular. This is shown, as an example, in FIG. **3**c which shows the trace of two strips **20** and where differently shaped triangular patterns **31** and **32** appear. For the clarity of the drawings, only those zones where the material **2** appears have been shown with dashes.

Referring again to FIG. **2**, the laser beam F is partially reflected by the device **10** towards the vibrating mirror M_i, and is then deflected, by separation means S, towards a photosensitive cell C where it forms a light spot T. The cell C gives an electrical detection signal D.

This detection signal is used, as shown further below in FIG. **4**, to synchronize the scanning of the device **10** by the spot S_L with the pieces of information constituting the picture, which form the signal P.

To this effect, the spot S_L scans the totality of each column C, including the part in the reading zone Z_L. The pattern or patterns (**41, 42** in FIGS. **1**) of the reading zone Z_L enable the recognition (detection) of the beginning of a column. For, the nature of the patterns **41, 42** (reflecting the beam more than the medium **1** or less than it) and their thickness as the case may be (causing off-centering of the spot T on the cell C in the event of excess thickness) cause variations, in the amplitude of the detection signal, which are characteristic of the start of a column. It must be noted that this detection cannot be realized on the column of the picture zone since the material **20** or **21** is there covered by the absorbing layer **3**.

In an alternative embodiment, the patterns **41, 42** may vary from one column to the next one, thus further enabling each column to be identified.

FIG. **4** shows an embodiment of the electronic means for controlling the device according to the invention.

The electrical detection signal D is transmitted, after amplification in an amplifier **40**, to a circuit **43** for the recognition (detection) of the beginning of a column.

Under the control of a timing device **45**, comprising a clock and counters, the circuit **43** gives a signal corresponding to the instant T_O of the beginning of the column of the picture zone Z_I. This signal may be, for example, the change of a binary signal to the state **0** and is intended for an AND gate type of logic circuit **46** which itself gives the modulator control signal P. In this embodiment, the signal indicating the instant T_O goes, before being transmitted to the AND gate **46**, to a circuit for determining the instant T_1 of the end of a column. This determining process is done from the instant T_O, by the addition of a constant interval corresponding to the time taken by the beam F to scan the column. In this example, the signal indicating the instant T_1 is formed by the same logic signal changing to the state **1**. The circuit **44** is controlled by the timing circuit **45**.

In the alternative embodiment shown in the figure, the device also has a comparator **47**, comparing the detection signal from the amplifier **40** with a threshold. This enables the detection of an outgoing, if any, of the laser spot S_L outside a strip **20**. For, in this case, the difference in reflective power between the material **2** and the substrate **1** causes a variation (for example a reduction) in the amplitude of the signal D. The output signal of the comparator **47** is also connected to the AND gate **46**. This AND gate again receives the information I to be recorded in the device **10**, in synchronism

with the instants T_O and T_1, by means of a buffer memory for example.

The AND gate thus has the function of permitting the passage of the information I when the spot S_L is in the picture zone Z_1 (between the instants T_O et T_1) and, if necessary, only when it is properly aligned with a column through the action of the comparator **47**. Finally, the timing device **45** controls the motion of the mirror M_y.

We have thus described a device on which a picture can be recorded by means of a laser beam, electrically controlled by a binary or non-binary signal representing the picture, giving excellent rendering which is difficult to counterfeit and difficult to falsify.

It must be noted that the reading zone part of the device is not necessarily made on the same medium as the picture zone. In any case, it is separated from the latter after recording the picture, in order to prevent the recognition of the column C.

It must also be noted that a picture can be recorded in color provided that, in the picture zone, there are microsurfaces **21** of different colors in a pre-defined arrangement (for example, in squares having four colors: blue, yellow, red and black) and that the laser beam is controlled accordingly.

The above description has, of course, been given as a non-restrictive example, and alternatives are possible within the scope of the invention. Thus, for example, it is possible to deposit an additional layer on the absorbent layer **3**, this additional layer being transparent, having a thickness of the order of a half wavelength of the laser radiation and having the function of matching the air with the layer **3**, thus restricting reflections on the surface of the layer **3**. Thus, again, there has been described (FIG. **2**) a motion of the device **10** with reference to the optical means but, of course, this is a relative motion and the optical means can also be in motion, with the device **10** being fixed if required.

What is claimed is:

1. A method for recording a picture on a medium device by means of a laser beam, said medium device comprising:

a substrate

a layer of a first material, arranged in columns on said substrate, said layer forming a picture zone and a reading zone;

a layer of a second absorbent material, capable of being destroyed by the laser beam, laid on said picture zone of said first material;

the laser beam being capable of a double relative motion with respect to the medium device:

a first fast motion along a first axis;

a second motion, slow in comparison with the first motion, along a second axis;

the laser beam being guided on said columns by means of said reading zone and the power of the laser beam being modulated, as a function of said picture, in synchronism with said first motion so as to destroy or not destroy said second material, thus revealing or not revealing said first material, the zones of said picture zone where the first material is revealed forming said picture, said reading zone being removed after said recording.

2. A device for the recording, according to claim **1**, of a picture on a medium device, said recording device comprising:

means to produce the laser beam;

means to modulate the power of the laser beam in accordance with an electrical signal representing the picture to be recorded;

means to ensure the scanning by the laser beam of the medium device along the first axis;

means to guide the laser beam on the columns of the medium device;

means to synchronize this position with the picture to be recorded.

3. A medium device for recording a picture with a laser beam by means of the method according to claim **1**, comprising:

a substrate

a layer of a first material arranged in columns on said substrate, said layer forming a picture zone and a reading zone;

a layer of a second absorbent material deposited on the picture zone of said first material; the ablation of said second material being capable of revealing the first material in a configuration forming said picture;

said reading zone being removable from said picture zone after said recording.

4. A medium device according to claim **3**, wherein said first material is deposited on said substrate along continuous columns.

5. A medium device according to claim **3**, wherein the first material is laid on said substrate in microsurfaces aligned according to said columns.

6. A recording device according to claim **5**, wherein said microsurfaces have different colors, thus enabling the recording of the picture in color.

* * * * *

United States Patent [19]

Taniguchi et al.

[11] **Patent Number: 4,847,184**

[45] **Date of Patent: Jul. 11, 1989**

[54] **METHOD FOR PRODUCING A LASER-PRINTED PICTURE**

[75] Inventors: **Itaru Taniguchi,** Osaka; **Toshiya Katsuragi,** Hyogo, both of Japan

[73] Assignee: **Kanzaki Paper Manufacturing Co., Ltd.,** Tokyo, Japan

[21] Appl. No.: **10,317**

[22] Filed: **Feb. 3, 1987**

[30] **Foreign Application Priority Data**

Apr. 21, 1986 [JP] Japan 92981

[51] **Int. Cl.**^{4} **G03C 5/00**

[52] **U.S. Cl.** .... **430/346;** 430/945; 346/76 L

[58] **Field of Search** .... 430/346, 945, 198, 297; 346/76 L; 144/3 N; 432/13; 250/330; 427/55

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,394,661	7/1983	Peeters	346/1.1
4,419,750	12/1983	Howe	369/111
4,520,370	8/1985	Fujii et al.	346/76 L

Primary Examiner—Jose G. Dees
Attorney, Agent, or Firm—Morgan & Finnegan

[57] **ABSTRACT**

Method for producing a picture on the surface of a substrate by laser-printing comprising the steps of:

generating still video information consisting of a series of gradational signals each of which corresponds to each of picture elements within a predetermined frame;

preparing a substrate having a surface carbonizable or discolorable with heating;

generating a laser beam having a sufficient energy to cause the carbonizing or discoloring of said surface;

modulating the laser beam in accordance with said video information;

scanning the modulated laser beam in accordance with said video information within said frame; and

directing and focusing said scanned laser beam to form a sweeping spot over the surface area of said substrate corresponding to said predetermined frame, thereby producing a graphic pattern consisting of picture elements individually gradationally carbonized or discolored.

It is preferred at or after said preparing a substrate, and before said directing and focusing the laser beam to the surface thereof that a carbonizing acceleration agent is applied and penetrated to the surface.

16 Claims, 2 Drawing Sheets

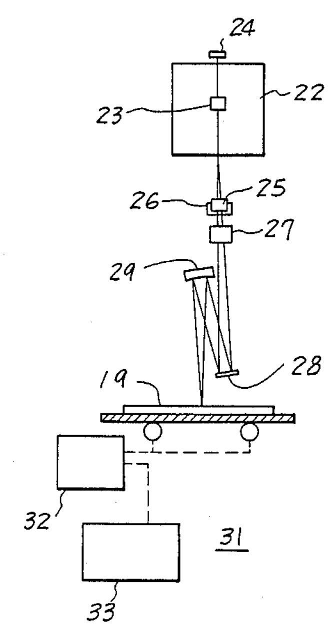


Fig. 1

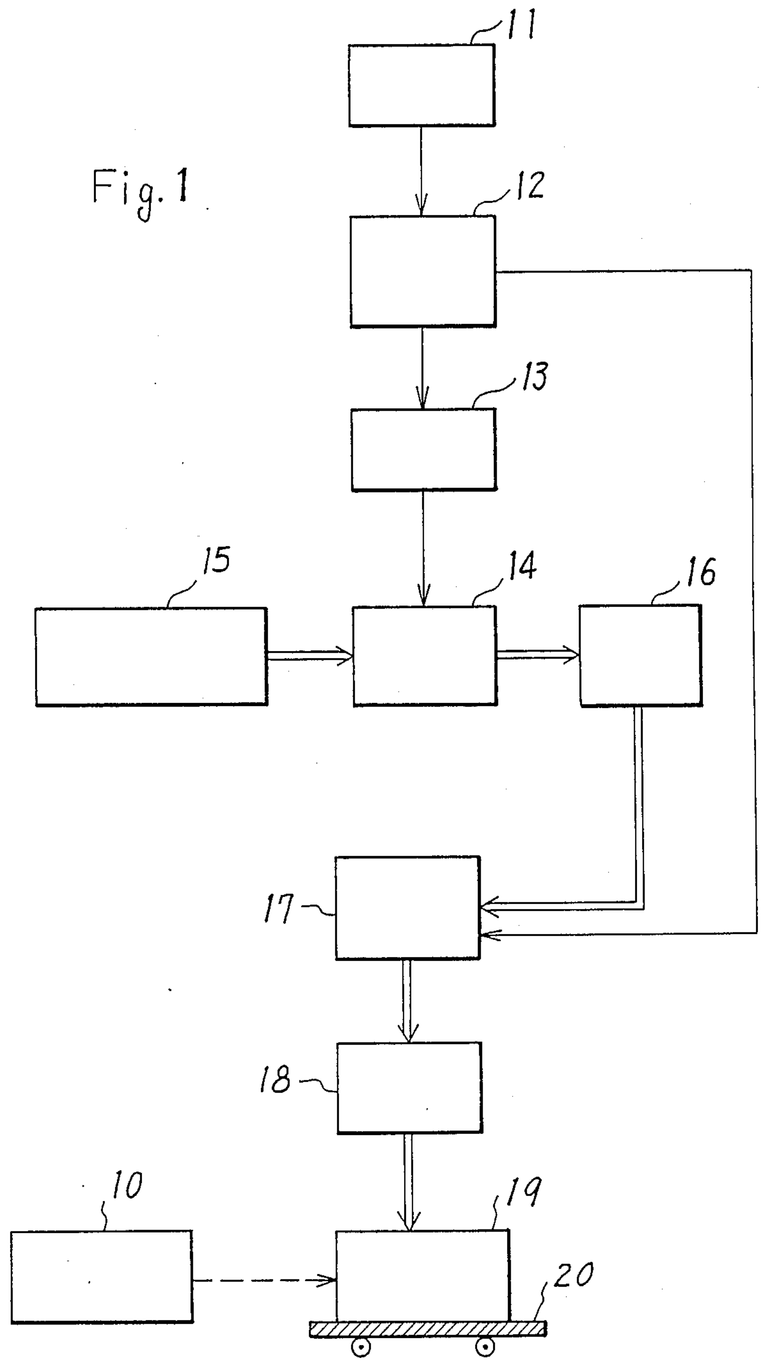


Fig. 2

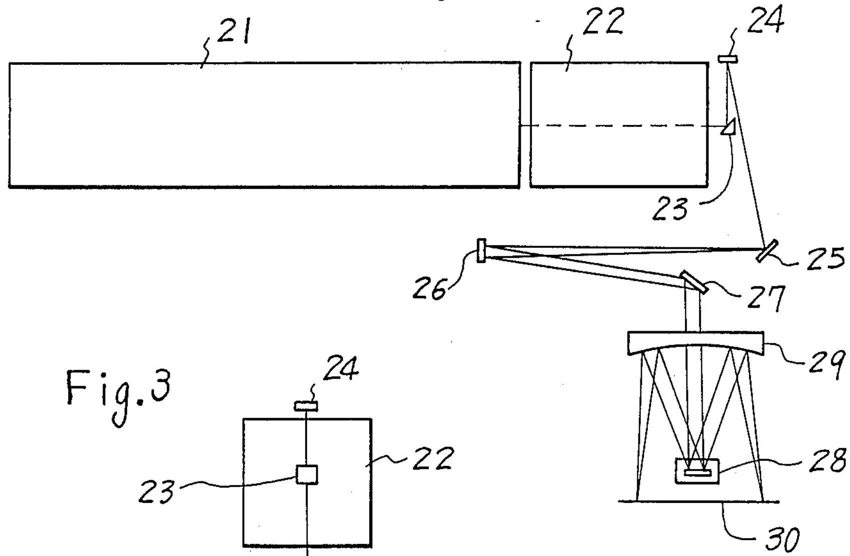
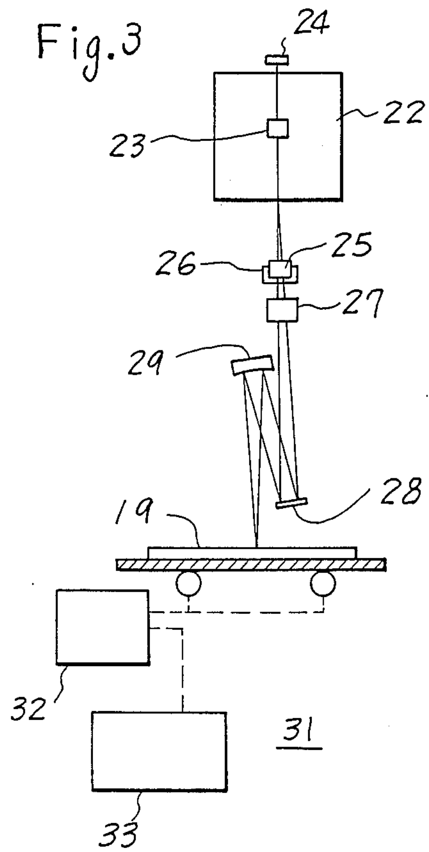


Fig. 3



METHOD FOR PRODUCING A LASER-PRINTED PICTURE

TECHNICAL FIELD

The present invention relates to a method for producing a high-quality laser-printed picture on a sheet-like or cylindrical substrate containing wood and/or carbonizable or discolorable constituents.

BACKGROUND ART

Conventionally, carved or printed matters exhibiting figures and/or characters on a sheet substrate or a printing block are made by any contact system using cutlery, or the like. However, recently such carved or printed matter became also made by non-contact system, which mainly uses laser beams. For example, using YAG laser system, it provides means for printing country name, model, and name on the product-name plates of automobiles, motors, and valves or on the surfaces of bearings and electronic parts complete with factory processes, or printing desired numerals, symbols, figures, and the like on ultra-rigid metal, rubber, cloth and plastic surfaces.

To realize the noncontact system mentioned above, there are a variety of systems including masking method for hallmarking through masks made from copper or stainless steel, internal modulation method for internally turning laser-oscillated voltage ON and OFF synchronous with laser scanning operation against materials, or method of applying mechanical shutter synchronous with laser scanning operation. Although these methods eliminates defects from conventional contact systems, quality of the printed and drawn figures or characters are expressed by binary codes, while picture elements are not arranged in the gradational manner. When individually observing these systems provided by the prior art in particular, the internal modulation system and the mechanical shutter system both eliminate mechanical elements for moving the processing object in the directions X and Y. However, only a two-dimensional or plane picture can be evaluated in conjunction with both of these systems, while no sculptural picture can be generated from these systems.

DISCLOSURE OF THE INVENTION

The primary object of the present invention is to provide a novel system and method intended for making sculpturally and gradationally printed pictures by irradiation of laser beams. Another object of the present invention is to provide a novel picture-formation process including steps for promoting carbonization of substrate material when generating patterns constituted from arranged picture elements printed or baked on substrate in the gradational manner.

More particularly, the picture producing process reflecting the first aspect of the present invention comprises the steps of: generating still video information to comprising a series of gradational electrical signals, each corresponding to a picture element within the predetermined frame; preparing substrate material having surface that can thermally be discolored or carbonized; generating laser beams containing sufficient energy to promote either discoloration or carbonization of the prepared material; modulating laser beams in accordance with the video information included in the predetermined frame; scanning the modulated laser beam in accordance with said video information; and directing and focusing the scanned laser beams to the surface of the substrate to generate a sweeping spot to form successive picture elements within the surface area of the substrate corresponding to the predetermined frame thereby generating pictures composed of such picture elements which have gradationally been discolored or carbonized within the above surface area.

A printed unit disclosed in Japanese Patent Application No. 30,988 or 1982 titled as "Laser Thermal Printer" can be used by improving a part thereof, expanding and modifying its function for generating still video information and eventually producing pictures on the surface of selected materials. In brief, the system of producing a laser-printed picture according to the present invention uses either a sheet-like or a cylindrical substrate material substituted for the thermal web used in the laser thermal printer of the above patent application. The system according to the present invention irradiates laser beams containing thermal energy specifically modulated in accordance with the gradational degree per dot (i.e., picture element) onto the surface of the selected substrate material following the predetermined picture-producing pattern without using such a thermal head coming into contact with the surface of selected substrate material, in which modulated laser beams are not generated by causing each dot to turn ON and OFF like the procedure disclosed in the preceding patent application.

The process of producing a laser printed picture of the invention introduces therein such modulation manner as to continuously and gradationally vary the outgoing scan beams according to the desired picture-producing pattern including an acousto-optic (A/O) modulation system, an electro-optic (E/O) modulation system, or a magneto-optic (M/O) modulation system for example.

According to the second aspect of the present invention, in order to produce a gradationally laser-printed picture, the picture-producing substrate having carbonizable surface containing cellulose is first prepared before coating or impregnating carbonization accelerating agent onto or into the prepared material. Then the surface of the substrate is irradiated with modulated scanning laser beams.

ADVANTAGES

Conventionally, when applying an acousto-optical modulator, the deflective light intensity V is calculated by applying the equation shown below using Bragg diffraction area.

$$V = 2 \cdot \left(\frac{\pi}{\lambda}\right)^2 \cdot (Mz) \cdot \left(\frac{L}{H}\right) \cdot Pa$$

where Mz denotes physical constant and Pa denotes an ultrasonic power.

More particularly, the light intensity is proportional to the linear function of ultrasonic power and inversely proportional to the second power of light wave-length, while light intensity itself is dependent on the sectional from L/H of ultrasonic-applied material and proportional to the combination of physical constants of the ultrasonic-applied material.

Concretely, multiple-gradational modulation can be realized by varying the ultrasonic power in accordance with multiple-gradational data related to the original

picture information. Energy of deflected laser beams applicable to the printing or the picture formation is directed to the scanning system via a laser-expanding mirror and a reflected-optical-path bending mirror. The scanning system can effectively use either a galvano mirror which is substantially the oscillating reflection mirror capable of varying angles in accordance with current delivered to solenoid or a polygonal mirror. It is also possible for the scanning system to directly scan laser beams by applying optical fibers. Then, the scanned laser beams are directed to the surface of F.θ mirror being opposite from the prepared material at the end of the scanning system. The scanned laser beams then reflect themselves in accordance with the scanning angle of the scanner before eventually arriving at the corresponding spot position inside the predetermined frame area on the surface of the prepared material. The modulation factor M of the acousto-optic modulation system using cadmium-telluride (Cd-Te) single-crystal is denoted by the equation shown below.

$$M = \sin^2\left(\frac{\pi n_o^3 \gamma \cdot L \cdot Vapp}{\lambda d}\right)$$

where L denotes the length (mm) of Cd-Te single-crystal, Vapp:the voltage (Volts) applied to Cd-Te single-crystal, d:the aperture (mm) of Cd-Te single-crystal, λ:the wave-length (μm) of laser beams, n_0:the refractive index of Cd-Te single-crystal/λ (μm), and γ:the first electro-optic coefficient of Cd-Te single-crystal/λ (μm), respectively. Note that when $\lambda = 10.6$ (μm), $n_0^3 = 10 \times 10^{-11}$m/V.

Multiple gradational analog-to-digital (A/D) conversion can be achieved at a very fast speed in accordance with information of the original picture by employing an appropriate data-processing unit. Using a specific digital signal level thus generated, the system according to the present invention varies the modulation factor M by varying the voltage (i.e., Vapp shown in the above equation) being delivered to the laser-beam modulator. This varies the degree of the deflection of laser beams to cause the output laser beams to yary themselves in multi-steps so that either the multiple-gradational character printing or the multiple-gradational picture formation can eventually be achieved.

Application of carbonization-accelerating agent to the picture-producing substrate material effectively promotes dehydration from cellulosic and other sugar ingredients composing the substrate material itself, and allows a substantial increase of carbonized residual constituents in such materials subjected to pyrolysis during exposure to the irradiating laser beams. When the picture-producing substrate holds volatile matters, volume of water among the matters increases to constrain the growth of tar. As a result, more carbon is yielded to eventually allow formation of vivid and dense printed pictures.

The above and other objects and advantages of the present invention will be better understood from the following description in reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is the simplified block diagram of the system executing the laser-printed picture-producing process according to the invention;

FIG. **2** is the simplified schematic diagram of the laser-printed picture-producing apparatus according to the invention showing its front view; and

FIG. **3** is the side view of the laser-printed picture-producing apparatus according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the accompanying drawings, the present invention is described in more detail.

In FIG. **1** which is the simplified block diagram of the laser-printed picture-producing system of the invention, picture-reading device **11** includes either a video camera or any suitable photoelectric scanning means which can generate a series of gradational electric signals each of which corresponds to each of the picture elements of a video scene or original picture in a desired frame. The central processing unit (CPU) **12** is to process the series of gradational electric signals generated by picture-reading device **11** in order that these signals are synchronized with scanning signals suited for use with the frame which contains a picture to be produced on the objective substrate material. Memory associated with CPU **12** is to store the signals processed by the CPU **12** as picture or still-video data. Modulated-signal generator **13** is to generate modulation voltages to be applied to laser-beam modulator **14** which includes either a Ge acousto-optic modulator or a Cd-Te electro-optic modulator. Laser-beam oscillator **15** includes a CO_2 laser or a YAG laser to emit laser beams which are then modulated by laser-beam modulator **14**. Laser-beam optical system **16** is to adjust the sectional shape of laser beams output from laser-beam modulator **14**. Laser-beam scanning system **17** is to scan laser beams emitted from laser-beam optical system **16** in accordance with the scan-instruction signal from the CPU and memory **12**. The scanning beam exited from laser-beam scanning system **17** is already modulated by modulator **14** synchronous with the scanning signal, and thus, the scanning beam from the laser-beam scanning system **17** has a specific beam-intensity distribution for each horizontal scanning line in accordance with the corresponding one or predetermined rows of elements on the original video-scene or the original picture. Laser-beam focussing system **18** includes either an F.θ mirror or an F.θ lens focussing the scan beam and directing it as a picture elemental beam spot onto a picture-producing substrate **19**. The substrate **19** preferrably contains wood or cellulosic material. The picture producing substrate **19** is placed on material table **20** which continuously or intermittently moves in the direction perpendicular to the laser-beam scanning line, while the vertical-pitch interval of horizontal lines on the surface of the picture-producing substrate **19** is established by the movement of the material table **20**.

At least three, and preferably four gradations should be applied to the printing-density of picture elements as the corresponding gradational intensity of the laser beam, in the constitution described above. The CPU and memory **12** can preferably be an adequate computer. The system according to the invention can also effectively use the drawing function of a computer for replacing the function of picture-reading device **11**. Likewise, the system can project laser beams on all the picture elements in the frame while placing the picture-producing substrate **19** in stationary condition by gradually shifting the laser-beam scanning line in the vertical direction. Furthermore, when employing either the

basic material-table movement system or the table stationary system, the picture-producing process of the invention can correctly adjust the overall carbonization level or printing-density level by repeating scanning of laser beams in the fram as many times as desired.

According to the preferred embodiment of the invention, as shown in FIG. **1**, before placing the picture-producing substrate **19** on material table **20**, a selected carbonization accelerating agent **10** is applied either by coating or impregnation onto or into this material **19**. Carbonization of material **19** is accelerated by applying a selected carbonization accelerating agent solely by effect of promoting dehydration from cellulosic material and sugar constituents. Concretely, as described earlier, application of the selected carbonization accelerating agent causes carbonized residual matter to increase in the constituents subjected to pyrolysis. On the other hand, it causes volume of water to increase itself in volatile matter to effectively constrain the growth of tarry components, thus eventually resulting in the significantly improved carbon yield.

Inventors tested a wide variety of chemicals to analyze their aptitude for application to the carbonization accelerating agent needed for help carrying out the invention by classifying chemicals into specific groups shown below. (1) Oxidizing agent, (2) Reduction agent, (3) Metal hydroxide, (4) Acid, (5) Polyvalent metallic chloride, (6) Boric acid salt, (7) Aluminium compound, (8) Organic acid/salt, and (9) Others.

After confirming the test results, inventors compiled Tables 1, 2 and 3, in which those chemicals which proved to have significantly accelerated carbonization are denoted in Table 1, and those chemicals which proved to have slightly accelerated carbonization are denoted in Table 2, whereas those chemicals which proved to have totally failed to accelerate carbonization are shown in Table 3, respectively.

TABLE 1

		Chemicals which have significantly accelerated carbonization
1.	Oxidizing agent	$KMnO_4$, $(NH_4)_2S_2O_8$, NaClO, $NaIO_4$, $K_2S_2O_8$, $NaClO_2$, KIO_3, $FeCl_3$, $K_2Cr_2O_7$, $AgNO_3$, H_2O_2
2.	Reduction agent	Na_2S, NaF, $Na_2S_2O_4$, $NaBH_4$
3.	Metal hydroxide	LiOH, NaOH, $Ba(OH)_2$, (KOH)
4.	Acid	H_2SO_4, H_3PO_4, H_3BO_3
5.	Polyvalent metallic chloride	$ZnCl_2$, $SnCl_2$
6.	Boric acid salt	KBO_2, $K_2B_4O_7$, $Na_2B_4O_7$
7.	Aluminium compound	$NaAlO_2$
8.	Organic acid salt	Potassium hydrogen phthalate Potassium antimony tartrate
9.	Others	$FeSO_4(NH_4)_2SO_4$, Na_2HPO_4, $(NH_4)_2HPO_4$, $NaHCO_3$, Na_2CO_3, $NH_4H_2PO_4$, NaSCN, $Zn(NO_3)_2$, KI

TABLE 2

		Chemicals which have slightly accelerated carbonization
1.	Oxidizing agent	NH_4NO_3, $NaClO_4$, $(Na_2Cr_2O_7)$
2.	Reduction agent	$NaSO_3$, $NaHSO_3$, $Na_2S_2O_3$, $NaNO_2$, (ZnS_2O_4)
3.	Metal hydroxide	
4.	Acid	(HNO_3)
5.	Polyvalent metallic chloride	$NiCl_2$, $CaCl_2$
6.	Boric acid salt	
7.	Aluminium compound	High-basic aluminium salt Acrylic acid aluminium Aluminium sulphate, $K_2Al_2(SO_4)_2$
8.	Organic acid salt	Polyaluminium hydroxide Sodium acetate, Zinc acetate Barium acetate, Sodium citrate Sodium benzoate Sodium propionate Potassium sodium tartrate
9.	Others	$Mg(NO_3)_2$, $Ca(NO_3)_2$, $LiNO_3$, $ZnSO_4$, $(NH_4)_2SO_4$, NH_4Cl, $K_4Fe(CN)_6$

TABLE 3

		Chemicals which have not accelerated carbonization at all
1.	Oxidizing agent	$CuSO_4$, $Ba(ClO_4)_2$, $(NH_4)_2Cr_2O_7$, KNO_3, $Ba(ClO_3)_2$
2.	Reduction agent	Formic acid
3.	Metal hydroxide	
4.	Acid	HCL Citric acid, Succinic acid DL-malic (Apple) acid Itaconic acid
5.	Polyvalent metallic chloride	
6.	Boric acid salt	
7.	Aluminium compound	
8.	Organic acid salt	Ammonium acetate, Calcium acetate Zinc tartrate Sodium monochloroacetic acid
9.	Others	Cationic starch, Ethylenediamine Glycol, Monoethanolamine

Referring now to FIGS. **2** and **3**, the constitution of the laser-printed picture-producing apparatus related to the present invention is described below.

See FIG. **2**. The reference numeral **21** denotes CO_2 gas laser beam oscillator. Acousto-optic modulator **22** includes single-crystal germanium (Ge) elements for modulating laser beams emitted from CO_2 gas laser beam oscillator **21** into a nalogue powers. Laser beams modulated from acousto-optic modulator **22** are directed to galvano mirror **28** via bending mirror **23**, beam-expanding mirror **24**, bending mirror **25**, beam-expanding mirror **26**, and another bending mirror **27**. Scanner including galvano mirror **28** is provided with F.θ mirror **29** which reflects laser beams entered into a specific range corresponding to the scanning angle of scanner **28** before eventually allowing laser beams to arrive at the corresponding spot position on the objective material surface **30**.

FIG. **3** is the side view of the optical scanning system comprised of mirrors **23** through **27**, galvano mirror **28**, and F.θ mirror **29**, and in addition, FIG. **3** also denotes the detailed material-feeding system. This material-feeding system **31** dealing with material-table **20** as shown in FIG. **1** is provided with material-feeding stepping motor **32** and motor drive **33**, respectively.

The above preferred embodiment introduces a sealed-off type CO_2 gas laser beam oscillator having 75 W of power output and an acousto-optic modulator containing germanium elements which effectively uses photo Bragg diffraction generated by acoustic beams. To drive the above acousto-optic modulator, the laser-printed picture-producing system according to the present invention has introduced as a driver, analogue-type RF power-supply source having 70 MHz of the center frequency and 1 Vp-p($\pm$0.5 V-to-the ground) of the input video voltage and an RF amplifier capable of

amplifying the input power to a maximum of 50 W of the RF power. According to the test result, the above acousto-optic modulator has achieved analogue modulation (i.e., Bragg diffraction) by applying the input video voltage **1** Vp-p, at DC through a maximum of 1 GHz of frequencies, more desirably, 10KHz through a maximum of 3 MHz of square waves to the above driver. Also, according to the test result, at least 100 meters/min. of the printing speed was needed for generating 100 through 150 μm of the spot diameter for the primary light of the acousto-optic modulated light (i.e., Bragg diffration) and the picture-producing material made from wood. It was also possible for the system to apply zero-order light of the acousto-optic modulated light. This method enabled the system to execute printing operations at a speed of about 1.5 times faster than the above case.

When applying electro-optic modulator instead of the acousto-optic modulator during the test, the system introduced a sealed-off type CO_2 gas laser beam oscillator having a maximum of 16 W power output. Cadmium-telluride (Cd-Te) electro-modulator **22** properly controls electric field to be applied to the predetermined direction of crystals and modulates laser beams by means of Pockels effect.

To implement the needed test, the system used a squarewave oscillator generating ± 2.5 KV of peak value and 1 KHz through a maximum of 1 GHz, desirably 10 KHz through a maximum of 3 MHz of frequencies for driving the electro-optic modulator mentioned above. Galvano mirror **28** provided sufficient scanning speed in conjunction with the spot diameter of the laser beams incident upon the substrate material surface **30**. According to a test in which a wooden sheet was used for the substrate material, it was a necessary condition for the system to execute the printing operation at about 20 meters per minute of the print-line speed for achieving 100 μm of the thermal spot diameter. When using the system constitution described above, as a whole, modulated laser beams were directed onto the substrate surface with about 20% of attenuation, thus eventually allowing the system to achieve a minimum of 1 μm of the depth of printed or baked depth per dot at about 1000 seconds of the printing speed to fully produce satisfactory characters and pictures on an A-**4** size substrate material. Inventors confirmed that aluminium and gold proved to be significantly effective for application to reflection coating agent on those reflective optical system components **23** including galvano mirror and mirrors **24** through **29**.

INDUSTRIAL APPLICABILITY

As is clear from the foregoing description, the laser-printed picture-producing system according to the invention is effectively applied to sheet-like or cylindrical substrate material made from wood, plastics, rubber, cloth and other materials, while providing a novel method of producing vivid picture having an adequate depth in accordance with the gradation by applying modulated laser beams without causing thermal head to come into contact with the substrate material. Furthermore, the system according to the invention securely improves picture quality and the efficiency of the picture-producing processes by coating or impregnating selected carbonization accelerating agents onto or into substrate surface in advance of activating the system operation, or by merely applying it via spray means as required, thus resulting in the accelerated carbonization

of picture portion, which in turn produces the improved picture quality and better efficiency of the picture-producing processes as mentioned above.

While the preferred embodiment of the invention has been illustrated in detail, modifications and adaptations of that embodiment will be apparent to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention, as set forth in the following claims.

We claim:

1. A method for producing a picture on surface of a substrate by laser-printing, comprising the steps of:

generating still video information comprising a series of gradational signals, each of said signals corresponding to each of picture elements with a predetermined frame;

preparing said substrate surface, wherein said surface is carbonizable or discolorable with heating;

generating a laser beam having a sufficient energy to cause carbonizing or discoloring of said surface;

modulating the laser beam in accordance with said gradational video information;

scanning the modulated laser beam in accordance with said gradational video information within said frame; and

directing and focusing said scanned laser beam to form a sweeping spot over the surface area of said substrate corresponding to said predetermined frame, thereby producing a graphic pattern comprising picture elements, wherein said elements are individually, gradationally engraved, carbonized or discolored.

2. The method of claim **1** wherein the laser beam is generated by a CO_2 g as laser with the wavelength of about 10.6 μm.

3. The method of claim **1** wherein the laser beam is generated by a YAG laser with the wavelength of about 1.06 μm.

4. The method of claim **1** wherein the modulating of the laser beam is carried out by a Ge acousto-optic modulator.

5. The method of claim **1** wherein the modulating of the laser beam is carried out by a Cd-Te electro-optice modulator.

6. The method of claim **1** wherein each of said gradational signals has a magnitude at any one of at least three gradations.

7. The method of claim **1** wherein said substrate is made of wood.

8. The method of claim **1** wherein all the horizontal scanning lines by the laser beam are repeated along one reference line, while said substrate is shifted in the direction perpendicular to said reference line.

9. The method of claim **1** wherein said surface of the substrate is engraved in the depth according to the gradational discoloring or carbonizing of said surface by laser irradiation.

10. Method for producing a picture on the surface of a substrate with a carbonization accelerating agent by laser-printing, comprising the steps of:

generating still video information comprising a series of gradational signals, each of which corresponds to each of picture elements within a predetermined frame;

preparing a substrate having a carbonizable surface by applying a carbonizing acceleration agent to the surface,

wherein the agent penetrates the surface, and
wherein the substrate includes a constituent of cellulosic material;

generating a laser beam having a sufficient energy to cause the carbonizing or discoloring of said surface;

modulating the laser beam in accordance with said video information;

scanning the modulated laser beam in accordance with said video information within said frame; and

directing and focusing said scanned laser beam to form a sweeping spot over the surface area of said substrate corresponding to said predetermined frame, thereby producing a graphic pattern comprising picture elements individually gradationally carbonized or discolored.

11. The method of claim **10** wherein the laser beam is generated by a CO_2 gas laser with the wavelength of about 10.6 μm.

12. The method of claim **10** wherein the laser beam is generated by a YAG laser with the wave length of about 1.06 μm.

13. The method of claim **10** wherein the modulating of the laser beam is carried out by a Ge acousto-optic modulator.

14. The method of claim **10** wherein the modulating of the laser beam is carried out by a Cd-Te electro-optic modulator.

15. The method of claim **10** wherein each of said gradational signals for each picture element has a magnitude at any one of at least three gradations.

16. The method of claim **10** wherein said substrate is made of wood.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 4,847,184

DATED : July 11, 1989

Page 1 of 2

INVENTOR(S) : Itaru Taniguchi et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 1, line 33, "eliminates" should read -- eliminate --; line 38, a comma (,) should be inserted after "art"; line 58, delete "to".

In Column 2, line 9, "or" should read -- of --.

In Column 3, lines 21-25, in the equation, change

"
$$M = \sin^2 \left(\frac{\pi n_0{}^3 \quad \gamma.L.\ Vapp}{\lambda d} \right)$$
"

to read :

--
$$M = \sin^2 \left(\frac{\pi n_0{}^3 \quad \tau.L.\ Vapp}{\lambda d} \right)$$
--;

line 31, "γ: the first" should read -- τ: the first --; line 34, -- τ -- should be inserted before "= 10 x 10^{-11}m/V."

In Column 4, line 42, "or" should read -- of --; line 48, "preferrably" should read -- preferably --.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,847,184

DATED : July 11, 1989

INVENTOR(S) : Itaru Taniguchi et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 7, line 12, "diffration" should read -- diffraction --.

Signed and Sealed this

Twenty-eighth Day of August, 1990

Attest:

HARRY F. MANBECK, JR.

Attesting Officer

Commissioner of Patents and Trademarks

United States Patent [19]
Bossmann et al.
[11] Patent Number: 5,017,423
[45] Date of Patent: May 21, 1991

[54] **FIBER, FILAMENT, YARN AND/OR FLAT ARTICLES AND/OR NONWOVEN MATERIAL CONTAINING THESE, AS WELL AS A PROCESS FOR PRODUCING THE FORMER**

[75] Inventors: **Adelgund Bossmann**, Krefeld; **Eckard Schollmeyer**, Kempen, both of Fed. Rep. of Germany

[73] Assignee: **German Textile Research Center North-West**, Fed. Rep. of Germany

[21] Appl. No.: **930,876**

[22] Filed: **Nov. 14, 1986**

[30] **Foreign Application Priority Data**

Nov. 14, 1985	[DE]	Fed. Rep. of Germany	3540411
Sep. 10, 1986	[DE]	Fed. Rep. of Germany	3630769
Oct. 25, 1986	[DE]	Fed. Rep. of Germany	3636395

[51] **Int. Cl.**^{5} **D02G 3/00**
[52] **U.S. Cl.** **428/224**; 219/121.65; 219/121.66; 219/121.85; 264/22; 428/229; 428/399; 428/400; 428/401
[58] **Field of Search** .... 156/272.8; 219/121 L, 219/121 LE, 121 LF, 121 LH, 121 LJ, 121 LM, 121.85, 121.65, 121.66; 427/53.1; 428/400, 401, 224, 229, 399; 8/444; 264/22, 25; 104/157.61

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,560,291	2/1971	Foglia et al.	156/272.8
3,600,289	8/1971	Bragole	156/314
4,457,817	7/1984	Bobeth et al.	264/25 X
4,613,470	9/1986	Aftalion	264/22
4,629,858	12/1986	Kyle	219/121.85

FOREIGN PATENT DOCUMENTS

0117561	9/1984	European Pat. Off. .	
0173925	3/1986	European Pat. Off. .	
3138474	4/1983	Fed. Rep. of Germany	427/53.1
2053789	2/1981	United Kingdom .	

OTHER PUBLICATIONS

Japanese Patents Gazette, Feb. 25, 1976, Abstract J50069-310 (Asahi Chem Ind KK).
Article entitled: "Erzielung von Struktureffekten an Syntheseseiden durch Warmebehandlung mittels CO_2-Laserstrahlen[1])" pub. in Textiltechnik, vol. 31, pp. 545, et seq.
Article entitled: "An Indication of Molten Cellulose Produced in a Laser Beam", published in Textile Research Journal, vol. 44, No. 2, pp. 152-154.
van Veld et al., Morphology of Man-Made Fibers, 12 Journal of Applied Polymer Science, pp. 2709-2724, 1968.

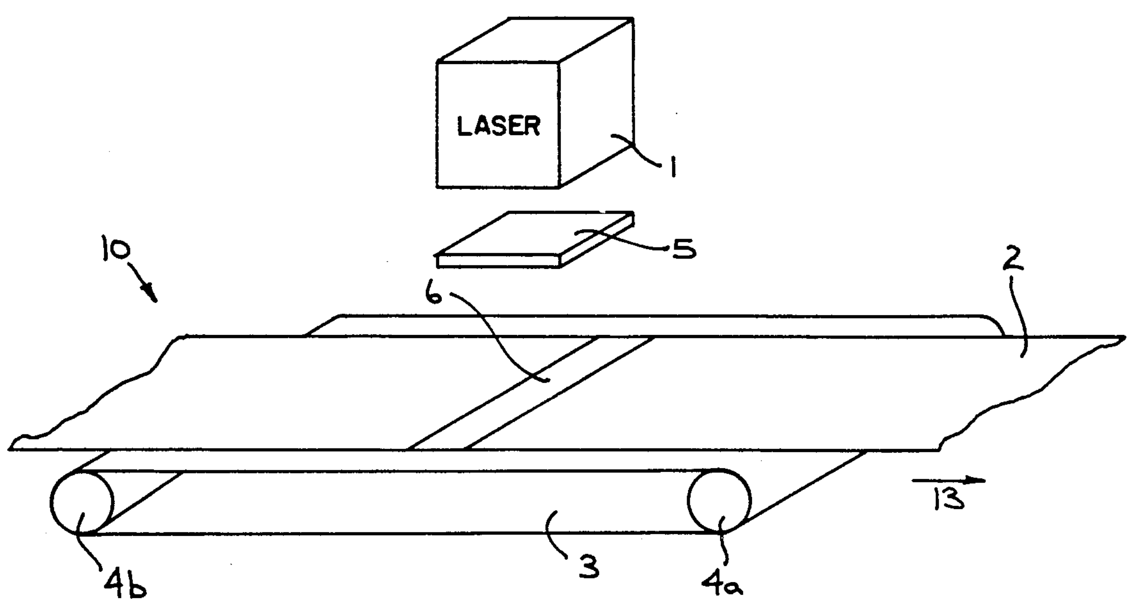
Primary Examiner—Michael Lusignan
Attorney, Agent, or Firm—Andrus, Sceales, Starke & Sawall

[57] **ABSTRACT**

A fiber, a filament, yarn and/or a flat article and/or nonwoven material containing these, which has on its surface a microstructure consisting of dotted, linear and/or areal depressions and/or elevations, which have a depth or height, respectively, up to ca. 10 micrometers and extend across ca. 10% to 100% of the surface of the fiber and/or the filament.

A process for the manufacture of the fiber, the filament, yarn, flat article and/or nonwoven material provides that the fiber, the filament, yarn, flat article and/or nonwoven material is irradiated with a laser, and that as a result its surface is fused, melted on and/or removed in a dotted, linear and/or areal fashion.

38 Claims, 3 Drawing Sheets



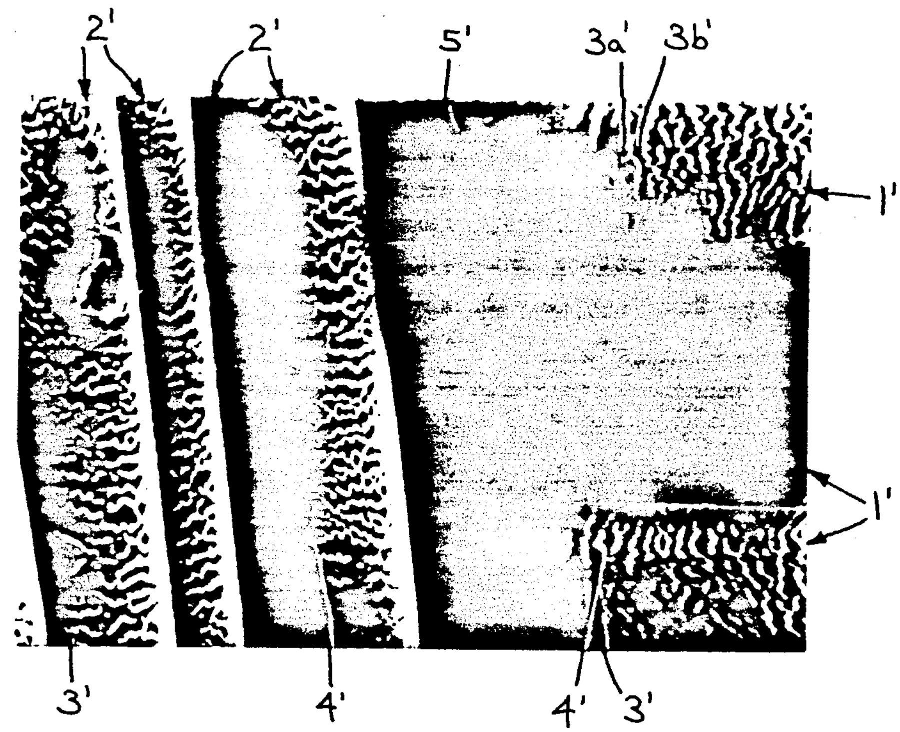


FIG. 1

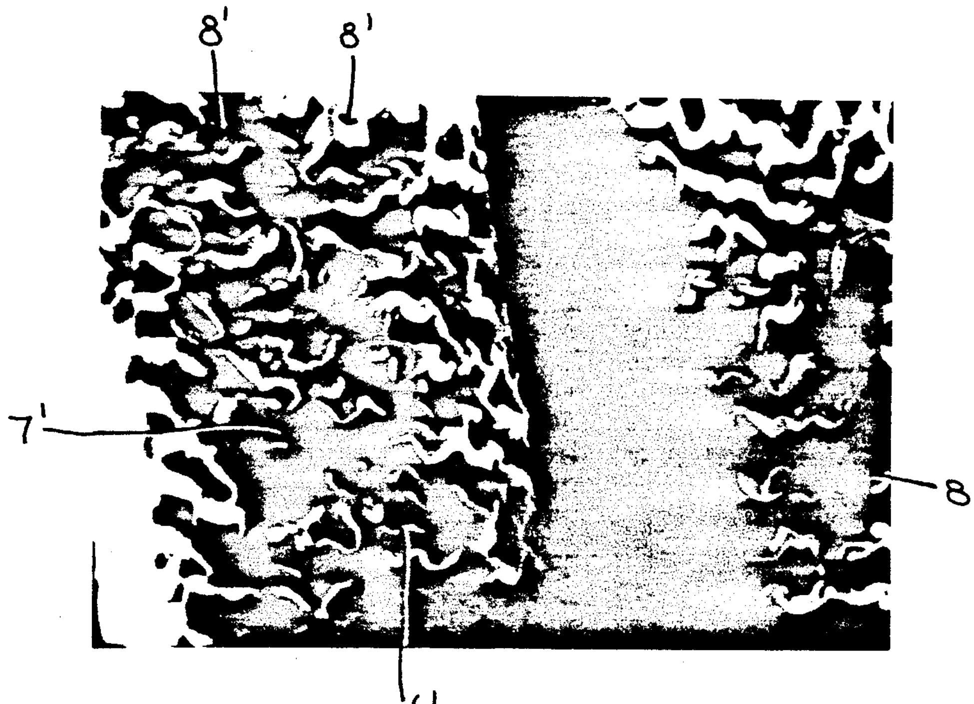
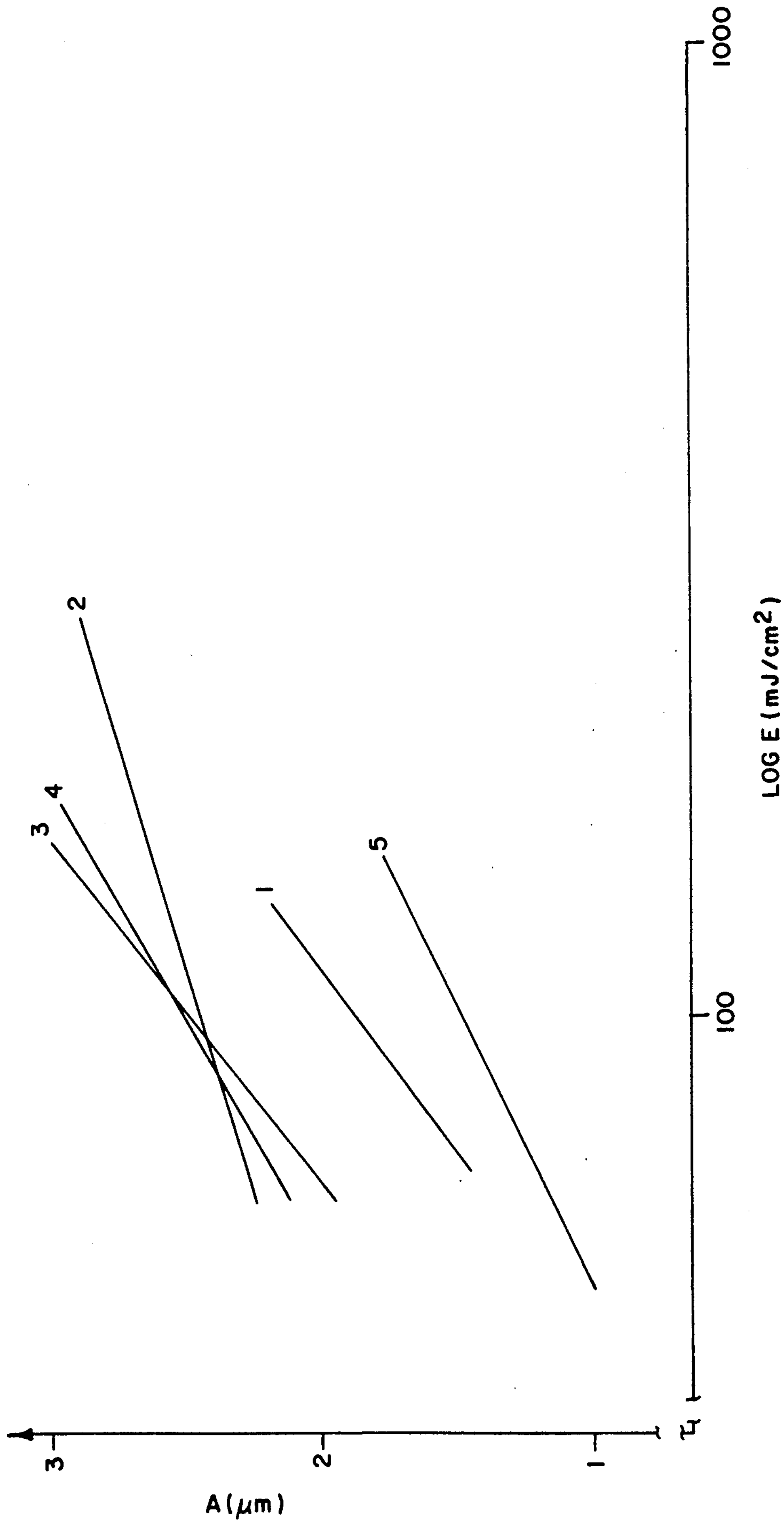


FIG. 2

FIG. 3



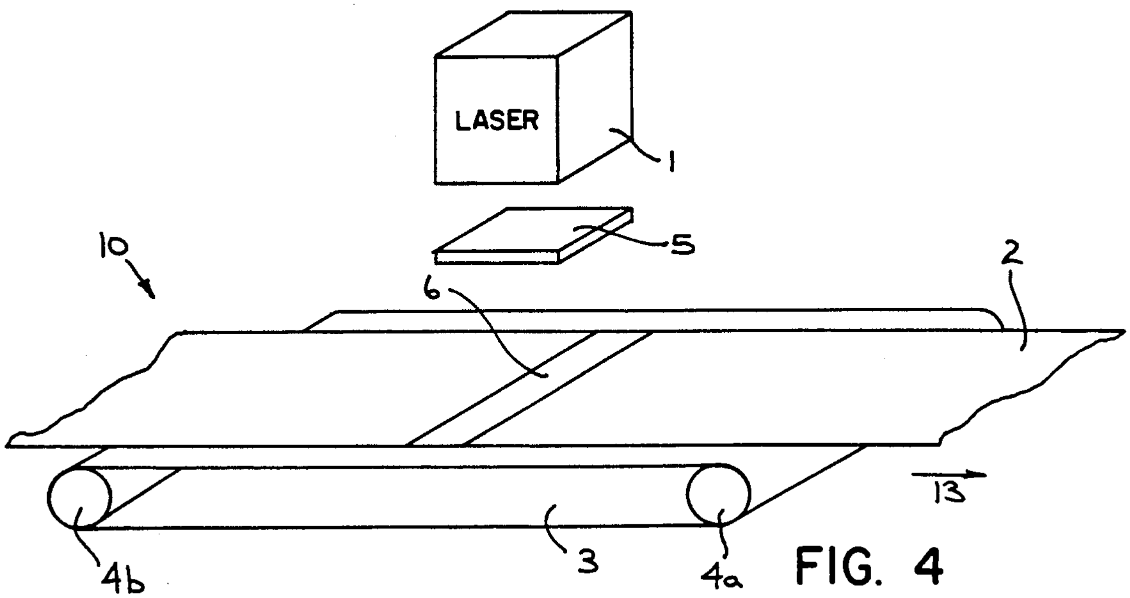


FIG. 4

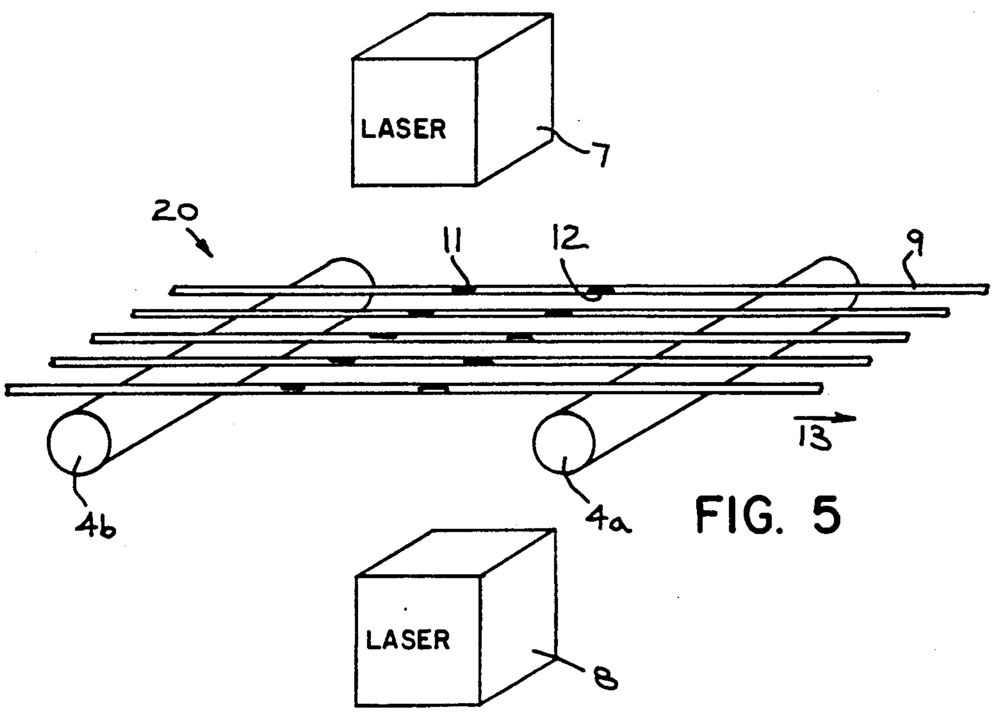


FIG. 5

FIBER, FILAMENT, YARN AND/OR FLAT ARTICLES AND/OR NONWOVEN MATERIAL CONTAINING THESE, AS WELL AS A PROCESS FOR PRODUCING THE FORMER

The invention concerns a fiber, a filament, yarns, flat articles and/or nonwoven or pile material containing these, as well as a process for producing the former.

There are known fibers, filaments, yarns, flat articles and/or nonwoven materials with varying surface structure. In synthetic polymer fibers, filaments, or the yarns made from these, this varying surface structure can be obtained, for example, by using spinning nozzles of differing designs during primary spinning, so that the fibers or filaments spun in this manner have a corresponding profile, which shows itself, for example, in a corresponding round, oval, triangular, starshaped or multicornered cross section. In addition, natural fibers, as for example cotton or wool yarns, can be changed by mercerizing or chlorinating. Here, the yarn is treated in an aqueous mixture containing alkaline or chlorine, that causes a change in the cross sectional shape of the cotton yarns and a change in the scale structure of the wool yarns; however, this is possible only within a small area without yarn damage, which manifests itself in varying dye affinity or printability or in loss of liquid. In addition, such processes do not structure, but rather smooth the surfaces.

In flat articles one must distinguish between the mechanical and chemical processes used to change the surface. Thus, mechanical processes are based on the fact that the surface of the flat article is embossed by means of a structured roller pair located in the calender in accordance with the structuring of the rollers. Here, the degree of embossing depends on the respective goods, the embossing temperature and pressure. Such surface changes caused by mechanical deformation have the disadvantage that in many cases they are not permanent and are no longer present after short-term use or after repeated maintenance treatment of the flat article. In addition, there is always the danger during the embossing process that dirt or yarn particles are deposited on the roller pair, which results in faulty and non-correctible deficiency of the goods. Also, due to the roller pairs which are used, embossing has limits set by the dimensions of the structuring, so that the latter usually has a length, width and depth of several millimeters and is therefore relatively coarse with respect to the dimensions of the fibers or filaments.

As for the chemical processes for changing the surface, the hydrolysis processes for flat articles of triacetate and polyester fibers must be mentioned in particular. Here, the flat article is usually treated for a certain time at a certain temperature in a mixture containing alkali, during which treatment, depending on the alkali concentration, treatment time and temperature, saponification of the fiber causes a denier decrease, while a structuring of the surface of the fibers, filaments or yarns used in the flat article does not take place. Rather, the surface of the fiber, or the filament or yarn, is smoothed by reduction.

DE-05 32 03 973 describes a process for the production of fibrillated fibers. Here, a polymer granulate is compacted to a certain bulk weight in such a manner that it contains gas occlusions. Subsequently the granulate is sintered to a certain depth, and an intermediate product is created. During this process the gases occluded in the intermediate product escape. This creates small blisters having craters on their surface, which blisters are distributed over the cross section of the intermediate product. Subsequently, the intermediate product is stretched out of its natural shape, and it is at this point that the actual fiber is produced, while the stretching causes the craters on the surface to burst as the fibrils are formed. Consequently, a fiber produced in this manner has on its surface merely contrasting fibrils which, however, have a length of over 100 micrometers.

It is the purpose of the invention to provide a fiber, a filament, yarn and/or flat article and/or nonwoven material containing these, which has an especially large specific surface and thus a specifically good adhesiveness. In addition, the invention creates a process for the production of such a fiber or such a filament, yarn and/or flat article and/or nonwoven material containing these.

This purpose is attained by the invention by means of a fiber, a filament, yarn and/or flat article and/or nonwoven material with the characteristics described in the patent claims and by means of a process with the characteristics described in the patent claims.

The invention's fiber, or the invention's filament, yarn, flat article and/or nonwoven material has on its surface a microstructure consisting of dotted, linear and/or areal depressions and/or elevations, which have a depth, or height, 25 respectively, of up to 10 micrometers or microns and extend across ca. 10% to ca. 100% of the surface, of the fiber and/or the filament. As a result of the microstructuring, the invention's fiber or the filament, yarn, flat article and/or nonwoven material has, as compared with traditionally formed fibers, filaments, yarns, flat articles or nonwoven materials, a considerably enlarged specific surface, which is the case particularly when the depressions, or elevations, respectively, extend over the entire surface of the fibers, or filaments, respectively, which have been worked into the yarn, flat article or nonwoven material. Such an increase in the specific surface includes a series of advantages.

To begin with, it improves the adhesiveness, for example with coatings, gluings, pigments with bonding systems or similar items, since these coatings etc. are not only more strongly absorbed or adsorbed because of the increased roughness of the surface, but also because they are much more firmly deposited and bound in the surface and with much greater resistance to mechanical stresses. Also, because of the microstructure and the concomitant roughness, the frictional resistance between the fibers or filaments which have been worked into a yarn, flat article or nonwoven material is increased, so that their movement relative to each other is considerably more dificult. In the case of yarns, this results for example in increased strength, and in the case of flat articles or nonwoven materials it results in an improvement of sliding resistance and possibly of seam strength. Likewise, the absorptive capacity of the microstructured surfaces of the fibers, filaments, yarns, flat articles and/or nonwoven materials is increased, which manifests itself, particularly in synthetic fibers, as improved physiological and/or permanent antistatic properties. As a result of the increase of the specific surface the invention's fibers, filaments, yarns, flat articles or nonwoven materials have excellent filtration properties, so that they can be used particularly well, for example, for the production of filters for the filtration of bever-

ages or for the separation of fine dust in room climate controls. The invention's fibers, filaments, yarns, flat articles and/or nonwoven materials also offer a series of advantages in the field of medicine. They can be used, for example, for the production of surgical sewing material or prosthetic articles, such as artificial veins, which have considerably greater resorptive capacity as compared with traditional fibers, filaments, yarns, flat articles or nonwoven materials. Likewise, microstructured hollow fibers used in artificial kidneys have considerably improved exchange coefficients as compared with traditional hollow fibers.

In the area of fiber-reinforced materials, as, for example, fiber-reinforced plastics, tires, or fiber-reinforced concrete, the microstructured surfaces of the fibers, filaments, yarns, flat articles and/or nonwoven materials have, as a result of the improved surface roughness, improved adhesiveness to the matrix surrounding them, as, for example, rubber, plastic or concrete, which manifests itself, for example, in longer surface life and increased strength.

Depending on the respective application and the concomitant required or desired surface enlargement, the depressions and/or elevations of the microstructure can also extend over only part of the surface of the fiber or the filament, for example between ca. 20% and ca. 80%. The general rule is that the size of the microstructures area decreases with increased working-in of the fiber or the filament into the yarn, flat article or nonwoven material. Thus, in case of relatively loosely adjusted yarns, flat articles or nonwoven materials, the depressions and/or elevations of the microstructure extend preferably over ca. 60 to 80% of the surface of the fibers or filaments worked into the yarn, flat article or nonwoven material, and in relatively densely adjusted yarns, flat articles or nonwoven materials they extend over ca. 40 to 60% of the surface of the fibers or filaments worked into the yarn, flat article or nonwoven material.

In a preferred version of the fiber, filament, yarn flat article and/or nonwoven material of the invention, the microstructure is formed as linear depressions and/or elevations, which extend mostly transversely to the longitudinal axis of the fiber or the filament. The linear depressions and/or elevations have depths, or heights, respectively, between ca. 0.1 micrometer and ca. 2 micrometers, preferably between ca. 0.5 micrometer and ca. 1 micrometer, and widths up to ca. 1 micrometer, preferably between ca. 0.3 micrometer and 0.6 micrometer. Their mutual distance is between ca. 1 micrometer and ca. 5 micrometers, preferably between ca. 1 micrometer and ca. 3 micrometers.

In addition the fiber, filament, yarn, flat article or nonwoven material of the invention can include reacting groups, such as, for example, basic or acid groups, in the area of the surface of the fiber or the filament. Preferably the area is that section of the fiber or filament surface which includes the above-described microstructure.

The invention's process for the production of the above-described fiber, the filament, yarn, and/or flat article and/or nonwoven material containing these, is built on the basic idea not to change the surface of the fiber, filament, yarn, flat article and/or nonwoven material by mechanical deformation, as in the above-mentioned state of technology, but by means of dotted, linear or areal fusing, melting-on and/or reduction, the necessary energy being generated by a laser. By synchronizing the wave length and energy of the laser beam and the size or form of the irradiated area with the respective substrate to be treated, it is possible to provide the surface of the fiber or the filament with a variably formed microstructuring, which at the same time causes a corresponding enlargement of the surface, as well as to partially reduce the surface as viewed toward the cross-section, and thus to obtain a denier reduction.

Such a process, as compared with the above-mentioned state of technology, has a series of advantages. It is possible, for example, to use the invention's process in an especially simple manner with fibers, filaments or yarns on the one hand, and with flat articles and nonwoven materials on the other, since the above-described surface structuring or denier reduction occurs without contact. For this reason the device used for such a process does not need special equipment adjusted to the geometry of the respective substrate to be treated, such as, for example, correspondingly formed roller-pairs in the known calender. In addition, the surfaces created by the invention's process are, as described above, very finely structured, while this structuring is permanent in subsequent use and especially with respect to extreme maintenance treatments, since it is not based on a mechanical deformation of the surface, as in the state of technology cited above, but rather on fusing, melting-on or reduction of the same. Also, as compared with the known processes the invention's process is considerably safer for the environment, since chemicals such as chlorine or lye solutions are not required for structuring the surface. Furthermore, rinsing or treatment baths heated to corresponding temperatures are not necessary, which thus results in energy and water savings. Also, in the invention's process the derivative products of the fibers or filaments generated during the microstructuring or denier reduction do not get into the waste water, since they evaporate due to the energy provided by the laser and can be separated from the exhaust air with relatively little effort, for example by means of correspondingly designed filters or condensers.

In the invention's process, the choice of the laser is based on the fiber substrate to be treated and on the respective energy, wave length and power of the laser-generated beams. Basically any laser can be used which can generate beams with a corresponding energy, wave length of power which is sufficient to accomplish the above-described fusing, melting-on or reduction of the surface. Thus, for example, rare gas ion lasers are suitable, such as Ar or Kr ion lasers that operate in a wave length range between ca. 400 nm and ca. 800 nm and which can be tuned to individual wave lengths. Likewise, the radiation can be accomplished with a Neodymium-Yag laser (Nd-YAG) with a wave length of 1 micrometer. CO-lasers with a wave length of 5.2 10 micrometers, or CO_2 lasers with a wave length between 9.6 to 10.6 micrometers can be used, too. Other gas lasers, which normally operate in a wave length range between ca. 157 and 351 nm, are also suitable, where wave length reductions can be effected by means of frequency multiplication. Especially suitable for generating laser beams are the Excimer lasers, which use as the laser medium, for example, F_2, ArF, KrCl, KrF, XeCl, N_2 and XeF and which generate beams with a wave length 157 nm, 193 nm, 222 nm, 248 nm, 308 nm, 337 nm, and 351 nm. The respective surface to be treated can be treated with a beam impulse as well as a permanent beam. With respect to the energy of a pulse beam one must consider that, with pulse duration between ca. 10^{-3} and 10^{-15} seconds, preferably between

ca. 10^{-3} and ca. 10^{-8} seconds, the energy should be between ca. 5 and ca. 500 mJ/cm^2, preferably between ca. 20 and ca. 50 mJ./cm^2. Of course, it is also possible to treat the fiber, the filament, yarn, flat article and/or materials with a multitude of laser beam impulses, preferably between ca. 5 and ca. 20, with a repetition rate of ca. 1 to 250 Hz, especially between ca. 1 to 5 Hz or ca. 200 to ca. 250 Hz.

In addition, the beams, or beam, generated by the laser can be expanded by means of a corresponding device placed in the beam path, so that in this way a larger area of the surface is irradiated. However, it is preferable to focus the beam or beams, in order to treat a correspondingly smaller surface area with increased radiation power or energy. By variation of the distance between the expansion or focusing device and the irradiated surface, the invention's process makes it possible to control the degree of surface structuring in an especially simple manner.

If the invention's process is used for finishing fibers, filaments and/or yarns, it is preferable to irradiate either the surface of the fibers or filaments or the surface of the yarn from all sides, regardless of the intended use. If the invention's radiation treatment is to be used for synthetic fibers or filaments, it would be advantageous to conduct the treatment immediately after primary spinning, since at this time the surface of the individual fibers or individual filaments, as viewed across their circumference, is still accessible from all sides. Such radiation should preferably always be conducted in such cases where the surface of the individual fibers or the individual filaments has a considerable effect on the properties of the finished products such as, for example, yarns, flat articles or bulk materials. If, for example, such fibers or filaments are used for the production of filters, the latter have considerably better filtering properties than traditional filters as a result of the enlargement of the surface. For the same reason, hollow fibers used in dialysis processes which have been irradiated as individual fibers have considerably higher exchange coefficients than non-radiated fibers. In addition, the surface enlargement increases fiber-to-fiber and filament-to-filament adhesiveness, which results in the fact that yarns or fleeces produced with these fibers or filaments have considerably greater strength and a better yarn of fleece cohesion.

Yarn should be irradiated especially in those cases where its surface decisively affects the properties of the finished product. This applies, for example, to yarns which are flocked or printed with pigmented coloring substances, since the flocking material or the pigmented coloring substance adheres considerably better to the yarn as a result of the surface enlargement or structuring obtaining by irradiation. For very densely adjusted flat articles or bulky materials it can also be recommended not to irradiate these, but instead the yarn used in their production, since the high material density makes it difficult to gain access from all sides to the surface of the yarns used in these flat articles or bulky materials.

It is of course also possible to use the invention's process with flat articles or bulk materials. Generally speaking, such treatment is suitable in such cases where the properties of the flat article or the bulky material depend decisively on irradiation-accessible surfaces of the fibers, filaments and/or yarns which have been worked into the flat article or the bulky material. Thus, for example, the invention's process can improve in flat

articles the sliding resistance, the adhesiveness to coatings and pigmented systems and the absorptive capacity, and thus the physiological properties, to a considerable degree, which is attributed to a corresponding surface enlargement or structuring. It is further possible, by using the invention's process, to change the feel, or fall, of the flat article as the result of the denier reduction in such a way that flat articles can be produced which are correspondingly looser and laterally drooping.

As far as the material of the fiber, the filament, yarn, flat article or nonwoven material is concerned, it must be generally noted that basically the invention's process can be used to treat any material whose surface can be correspondingly fused, melted-on or reduced. Preferably synthetic fibers, filaments and/or yarns and/or flat articles or nonwoven materials containing these are irradiated which contain, for example, fibers of polyester, polyamide, polyacrylnitril, polypropylene, polytetrafluortetraethylene, polyurethane, polycarbonate, acetate, triacetate, aramide, carbon, graphite and glass. The invention's process is also applicable for natural fibers, such as cotton fibers.

Another version of the invention's process provides that only certain sections of the yarn or flat article are irradiated in order to obtain pattern effects in this way. The cause for such pattern effects can be seen in a varying light reflection and/or matting which exists between the radiated and non-radiated sections. Such patterned irradiation can be achieved, either by moving an endless web of the yarn or the flat article relative to the laser and covering the laser radiation temporarily in a planned manner, or by moving instead a laser beam relative to the surface of the yarn or the flat article in a predetermined pattern which corresponds to the pattern which is to be created.

The last-mentioned process has the advantage that the surface of the yarn or flat article can be irradiated from all directions and that, therefore, patterns can be created which are primarily oriented in one direction. As already mentioned, the microstructuring causes a surface enlargement in the irradiated areas, with the result that, during subsequent dyeing, the irradiated areas have a greater dye absorption capacity and are thus colored more deeply and/or differently from the color shade.

There are two possibilities for using such a process, in which the laser beam is moved according to a predetermined pattern, in treating endless webs of yarns or flat articles. In one version of such a process the endless web is moved step-by-step over a certain distance, and during the stops of the web the light beam is moved across the respective web section according to the predetermined pattern. In the second version, the endless web of the yarn or the flat article is moved relative to the laser and the light beam is moved according to the predetermined pattern, while the conveying speed of the web and the speed of the light beam movement are synchronized. The first-mentioned version is particularly suitable for patterns running transversely to the direction of the web movement, and the second version is suitable particularly for patterns which are primarily oriented in the direction of the web movement.

In a further development of the above-described process, the wave length, energy and/or power of the light beam generated by the laser can be altered. This makes possible the production of patterns within patterns, since varying degrees of fusing, melting-on and/or re-

duction of the surface of the yarn or flat article are caused depending on the wave length, energy and/or power of the light beam. In addition, a bundle of light beams can be used to produce such interior patterns, where, for example, individual light beams have differing wave lengths. Likewise, a bundle of light beams can be used advantageously when relatively large-surface patterns are to be produced.

In order to achieve the above-described movement of the light beam in a simple manner, it is preferably to direct a light beam at the yarn or flat article which is reflected from a reflection device, such as, for example, a dielectric mirror, and to move the reflection device according to the predetermined pattern. Because of the relatively low weight of the reflection device it can be moved relatively quickly and easily, so that even relatively complicated, involved patterns can be produced. It is, of course, also possible to direct the light beam generated by the laser directly at the selected section of the yarn or the flat article and to move the laser according to the predetermined pattern; however, the relatively large weight of the laser necessitates a relatively expensive mounting of the latter.

Likewise, instead of a single light beam a bundle of light beams can be used, which is expanded or focused by suitable devices located in the light beam path, so that expansion permits the radiation of a greater area with relatively less power, and focusing permits the radiation of a correspondingly smaller area with increased power or energy. The degree of surface change and the respective irradiated area can be controlled in an especially simple manner by varying the distance between the expanding or focusing device and the laser, so that an additional possibility for patterning within the pattern exists.

The above-described process can be applied in various ways. For example, if pile fabric is chosen for this process and this pile fabric is irradiated from the right side, i.e. the pile side, with a relatively high light beam energy or power, pile articles with especially simple patterns can be produced in this manner, which have shortened pile nubs in the irradiated sections as compared with the non-irradiated sections. With the present state of technology, this type of patterned pile goods can be produced only at great cost by special weaving processes or by embossing, and embossed pile goods often lose their embossing with advanced use, especially after repeated cleaning. However, this can not occur with the invention's process, since the above-described shortening of the pile nubs is irreversible as a result of their partial reduction. If this type of process is applied to pile goods which have already been dyed, one gets a pile article which is patterned shade-in-shade, while the varying light reflection between the irradiated and the non-irradiated sections even heightens the pattern effects caused by shortening the pile nubs. On the other hand, if the pile goods are irradiated before dyeing, varying dyeability will also result, which manifests itself, for example, in a color difference and/or a shift of color shades. The possibility also exists to produce an internally patterned pattern by varying the wave length, energy or power of the light beam, in that the pile nubs within the pattern are reduced to varying degrees and thus have different lengths. If this is not desired, it is advisable during irradiation to reorient the pile goods, for example at an edge, in such a way that the light beam, or the bundle of light beams, can be directed at the nubs which are to be reduced without interference from the adjacent nubs. Especially good results are obtained if the pile goods are reoriented at an angle between ca. 120° and ca. 160°.

Likewise, such a process can be used in a particularly simple manner to produce burnout articles, for example of polyester or cotton yarns. In the areas of the flat article which are determined by the chosen pattern, the polyester portion of the yarn is reduced, so that, as the result of the removal of the polyester portion, the irradiated areas have, as compared with the non-irradiated areas, a considerably reduced material density, which stands off clearly as a pattern from the remaining areas. Such burning-out can not be done with the traditional processes, since the cotton portion is always oxydatively removed. Furthermore, as compared with the known process the invention's process has the advantage, that in the case of burn-out articles the removal of the polyester portion does not require any chemicals and expensive rinsing baths, since the polyester portion is removed by the laser beam's energy and the resulting derivative products can easily be removed from the exhaust air at relatively low cost, for example by means of suitably constructed filters or condensers.

Likewise, the invention's process can be used for flat articles which are coated on one side. These are, for example, the traditional coatings on a synthetic polymer base, such as, for example, polyvinylchloride, polyvinylacetates, polyvinylethers, polyurethanes, and similar types, or on a natural polymer base, as for example natural rubber. Flat articles coated in this manner have the disadvantage, that clothing items made from them, as, for example, shoes, weather protection clothing etc., have very poor wearing properties, since the impermeability of the coating does not permit any vapor exchange between the body of the user and the ambient atmosphere. If, on the other hand, a flat article coated in this manner is irradiated on its coating side by a light ray generated by a laser beam in such a way that, in accordance with a predetermined pattern, the coating in the irradiated areas is reduced, preferably in dot-fashion, this will result in a coated flat article which is penetrated by micropores, while the micropores cause water vapor permeability, but no water permeability. Furthermore, use of the invention's process offers the possibility for providing, in selected areas of the flat article, an especially large number of such micropores, so that these areas can be used in subsequent clothing manufacture for making clothing sections such as armpit sections, where increased water vapor exchange is desirable because of increased transpiration. Thus, the invention's process permits the production of especially well coated flat article which, as viewed across their surface, have a graduated water vapor permeability.

Of course, it is also possible to conduct a bilateral irradiation of flat articles instead of the unilateral irradiation described above. However, this is done only in such cases where both sides of the flat article affect its properties. Thus, the process of the invention can be used, for example, to treat shaft-patterned weaves in such a way that the warp threads running over a longer stretch at both sides of the flat article, which are not tied into the basic weave outside the pattern, can be severed immediately at the edge of the pattern by the light ray generated by the laser. For this purpose it is suitable to chose a light ray whose energy, power or wave length is so great that it reduces several warp threads simultaneously across their profile, and in so doing glues the warp threads at their lower end to the basic weave,

which results in especially firm attachment of the warp threads, which are tied into the pattern over a relatively short distance.

If the invention's process is used for the production of patterned yarns, it is preferable to irradiate the yarns from all sides, as viewed across their profile. This can be achieved, for example, by irradiating the surface of the yarn simultaneously from various directions with several light rays, which are generated by a corresponding number of lasers, while the light rays are preferably reflected at the yarn surface by reflection devices placed concentrically around the yarn and being moved according to the predetermined pattern.

In order to prevent a chemical change in the surface of the irradiated fiber, filament, yarn, flat article and/or nonwoven material, it is advisable to surround these during irradiation with a protective or inert gas atmosphere. For this purpose, for example, nitrogen or rare gases are used. Likewise, the radiation can be undertaken in a vaccum. Such a method is required especially for substrates which are easily oxidizable at elevated temperatures because of their chemical structure, as this is the case, for example, with polyamides or polypropylenes.

If, on the other hand, a chemical modification of the surface is made in addition to its microstructuring, it becomes advisable to replace the above-described protective or inert gas with a reacting gas wholly or partly during laser irradiation. The energy required for the chemical modification is supplied by the laser beam or beams.

To explain the chemical modification of the surface occurring in this type of version of the invention's process it is assumed that, during the dotted, linear or areal fusing, melting-on and/or reduction of the irradiated surface, a corresponding splitting of polymer macromolecules located at the surface causes the formation of reactive centers. These reactive centers then react with the reacting gas present during the irradiation. Likewise, it is possible that the gas present during the laser irradiation is decomposed into a reacting condition simultaneously with, or exclusively because of, the laser irradiation, for example radicalization or ionization, and that the gas activated in this way reacts with the fused or melted-on surface of the fibers, filament, yarn, flat article and/or nonwoven material.

This type of process has the advantage that, as the result of the variations of the conditions of laser irradiation by changing, for example, the time, the irradiated area, energy and/or wave length, the supplied amount of gas and the chemical composition of the gas atmosphere, the respective obtained chemical and physical surface modification can be particularly well controlled. The general rule is that with increasing energy of the laser radiation and increasing reacting capacity of the gas or gases used, the degree of surface modification increases. In addition, in the invention's process, the chemical modification of the irradiated fiber, filament, yarn, flat article and/or nonwoven materials occurs preferably only in a limited surface area, as seen across the thickness, so that a loss of stability or changes of the other thermal-mechanical properties, such as, for example, the stress-strain behavior, do not take place.

Basically any gas which is reactive, or can be changed into a reactive gas by laser radiation, can be used for such a process. Acid or basic gases are preferable, which can be, for example, oxygen compounds with carbon, nitrogen and sulfur, and/or hydrogen compounds of nitrogen, and/or nitrogen-organic compounds, such as amines. Thus, for example, the use of carbon dioxide, sulfur dioxide or sulfur trioxide during irradiation can produce chemically modified surfaces, where the macromolecules located at the surface have additional acid groups. If, on the other hand, the macromolecules at the surface are to have additional basic groups, one merely has to use suitable gases during irradiation, such as amines or ammonia. Furthermore, in the invention's process the chemical modification of the surface can be conducted in such a way that the macromolecules have acid as well as basic groups. For this purpose one merely has to conduct the laser irradiation first in an acid gas atmosphere and then in a basic gas atmosphere or vice versa.

In a further version of the invention's process an interhalogen compound and/or a halogen-hydrogen compound can be used instead of the above-described gases. As a result, correspondingly halogenized macromolecules are created in the area of the irradiated surface, which molecules are available as reactive centers for further reactions, for instance reticulation or grafting reaction.

If an organic compound is used as the reacting gas, which compound has at least a double or triple bond, branching molecules can be created in selected areas of the surface, which in addition can still be oligomerized or polygomerized in the lateral chain, depending on the respective organic compound being used.

Likewise, nitrogen, carbon or oxygen-containing gases, such as methylisocyanate, can be used as reacting gases in the invention's process. Phosgene is also suitable in order to create reacting centers at the surface of the irradiated substances.

If the irradiated polymer substrate contains blocked reacting groups, as, for example, blocked isocyanates, these can be changed into a reactive state by radiation, which results in corresponding unilateral or universal surface reticulations.

In the invention's process where chemical modification of the surface is undertaken in addition to microstructuring, the choice of laser is based on the respective fiber substrate to be treated, the desired physical and chemical surface modification and the required energy, wave length and power of the laser beam. Basically any lasers can be used which are capable of generating light rays with a power which is large enough to achieve the desired microstructuring and the above-described activation of the irradiated areas of the surface and/or the gases used. The above-described lasers are preferably used for this purpose. In this type of version of the process it is, of course, also possible to treat the surfaces of the fiber, filament, yarn, flat article and/or nonwoven material entirely or in selected areas with a single laser beam, a laser beam impulse or a multitude of laser beam impulses, if the latter has/have the already mentioned powers and the above-mentioned repetition rate. The laser beam can also be focused or expanded, as this has already been described above. This permits a simple control, not only of the degree of microstructuring, but also of the degree of chemical surface modification.

Furthermore, this invention concerns a device for executing the process. Here, the invention's device includes a conveyor for an endless web of fibers, filaments, yarns, flat articles or nonwoven materials, and a laser, which is directed at the endless web and which generates the radiation. The conveyor transports the endless web continuously at a certain transport speed.

By synchronizing the transport speed, the area irradiated by the laser, and the power or energy of the generated beams with the respective substrate to be treated it is possible to control the resulting surface change, which manifests itself in a microstructuring and, as the case may be, in a chemical modification.

A further version of the invention's device provides that in the beam path between the laser and the endless web either an expansion device or a focusing device is placed, by which the surface of the irradiated area can be enlarged or decreased.

In order to create the possibility for irradiating the endless web from two sides, another version of the invention's device has a second laser, which relative to the web is located opposite the first laser.

A version of the invention's device which is particularly suited for fibers, filaments, or yarns is equipped with a reflection device instead of a second laser, which reflection device reflects the beams generated by the first laser in such a way that, viewed across their profile, the entire surface of the fibers, filaments or yarns is uniformly irradiated. Preferably, the reflection device is a dielectric mirror.

The invention's process can be applied in various ways. Thus, for example, it can be used for fibers, filaments, yarns, flat articles or nonwoven materials which are subsequently made into compact materials by coating, such as fiber-reinforced plastics. If the laser irradiation is conducted in the presence of a reacting gas, this results, particularly in synthetic fibers, filaments or yarns, not only in a microstructuring, but also in a chemical modification of the surface. Such synthetic fibers, filaments or yarns are, for example, polyester, polyamide, polyacrylnitril, polypropylene, polytetrafluoetheylene, polyurethane, polycarbonate, acetate, triacetate, aramide, carbon, graphite and glass fibers. This causes a marked improvement of the adhesion between the coating and the fibers, filaments, yarns, flat articles or nonwoven materials worked into it. The gas, or gases, used during the irradiation is/are adapted to the chemical composition of the coatings in such a way that such reactive groups are created in the surface area of the irradiated substrate by chemical modification, or grafting, which react with the coating, or generally, with the matrix, by creating a physical and/or chemical bond. The same applies to the treatment of the surfaces of textile polymers, which are used in metal-coated textiles, laminates, and metallized yarns or filaments which are utilized, for example, as protective clothing for radar rays, or for clean-rooms in the pharmaceutical or electrical industry. In addition, the microstructuring, alone or together with the chemical modification, causes in fiber-reinforced concrete an improvement of the bond between the concrete and the fibers, the flat article or nonwoven material worked into it. Likewise, a flat article or nonwoven material treated with invention's process can be used as the primary layer for compact material, such as brake disks or tire cord.

The fibers, filaments, yarns, flat articles or nonwoven materials treated with the invention's process also have application in the medical field. They can be used, for example, for the production of surgical sewing material or prosthetic articles, as, for example, artificial veins which, as compared with non-radiated, superficially not microstructured and/or chemically modified substrates, have a considerably greater resorptive capacity.

Likewise, microstructured hollow fibers used in dialysis have, as compared with non-irradiated hollow fibers, considerably higher exchange coefficients, which can be further improved by additional chemical modification of the surface. The same applies to filters which were made with irradiated fibers, filaments, yarns, flat articles or nonwoven materials. As compared with conventional filters they have considerably improved filtration properties, which is manifested, for example, by greater separating capacity, longer service life etc. Such filters are excellent for wet filtration, as, for example, sterile filtering of beverages such as beer, wine etc., as well as for dry filtration, especially for the separation of fine dust in cleanrooms or gas masks.

Advantageous futher developments of the invention's fibers, filaments, yarns, flat articles or nonwoven materials, as well as of the invention's process and the invention's device for implementing the process are stated in the subclaims.

In the following, the invention is explained in greater detail with the help of drawings and the use of forms of embodiment. Shown are:

FIG. **1** an electron-microscope screen photo of an area of irradiated polyester fabric, enlarged 800 times;

FIG. **2** an electron-microscope screen photo of an area of a polyester multi-filament yarn, enlarged 2,800 times;

FIG. **3** a graphic presentation of the distance of the depressions, or elevations, respectively, as a function of the energy density of the laser beams;

FIG. **4** a first form or embodiment of a device for the irradiation of flat articles; and

FIG. **5** a further form or embodiment of the device for the irradiation of yarns.

FIG. **1** shows an electron-microscope screen photo of an irradiated polyester fabric in 800× enlargement. A section of the fabric was irradiated with a KrF Excimer laser at a wave length of 248 nm; 10 beam impulses with a repetition rate of 5 Hz and an energy of 200 mJ/cm^2 per pulse were emitted by the laser. The transverse wefts as well as the longitudinal warps, which are fiber yarns, have a microstructure consisting of linear, wavy depressions **3'** and corresponding elevations **4'**, which are predominantly located transversely to the longitudinal axis of the fiber. The depressions **3'** or the elevations **4'** have a depth or height between ca. 0.6 and ca. 0.8 micrometer, and the distance between adjacent depressions **3***a'* and **3***b'* is between ca. 2 micrometers and ca. 3 micrometers. Their width is ca. 0.4 micrometer and ca. 0.6 micrometer, respectively. In addition, FIG. **1** shows non-irradiated areas **5'** in the weft material **1'**, which occurred because the warp material **2'** covered these areas **5'**.

The microstructure shown in FIG. **2**, which is an area of the surface of an irradiated polyester multifilament yarn which was treated under the above-described conditions, has, in addition to the above-described linear depressions and elevations, areal depressions **6'** and areal elevations **7**. These have an area of ca. 2 to ca. 4 micrometers^2 and a depth or height of ca. 2–3 micrometers. Their distribution is completely irregular across the surface of the fiber. In addition, dotted depressions **8'** are present, which have an area of ca. 1 micrometer^2 with a depth of 1 micrometer to 2 micrometers. These, too, are distributed irregularly across the surface of the multifilament yarn.

FIG. **3** shows the distance of adjacent linear depressions as a function of the logarithm of the energy density per pulse. Different fibers, or fabrics, were treated with varying wave lengths of the laser beam. In general

it must be noted here that the actual form of the microstructuring is determined by the first beam impulse, while the subsequent beam impulses essentially increase the depth of the depressions and the height of the elevations and change the distance only minimally. In the diagram shown in FIG. 3 only one beam impulse, respectively, was fired at the sample, with variations of the energy. The straight lines 1 and 3 apply to a polyester fiber with trilobal cross-section, the straight line 2 to a polyester sieve netting, and the straight lines 4 and 5 to two polyester sieve nettings. The straight lines 1, 2 and 5 were obtained by irradiating the samples with an ArF-Excimer laser at 193 nm, and the straight lines 3 and 4 were obtained by irradiating the samples with a KrF-Excimer laser at 248 nm, while the energy density of the beam impulses was varied in the area noted.

FIG. 4 shows a device which in its entirety is designated as 10, which is used for finishing flat article or nonwoven materials. This device has a conveyor, which consists of two rollers 4a and 4b, an endless conveyor belt 3 running between these rollers, and a draw-off device (not shown). The conveyor continuously transports an endless web 2 of a flat article or nonwoven material in the direction of the arrow 13 at a continuous speed. Above the endless web a laser 1 is located, which generates radiation. The beams generated by the laser 1 are directed at the web by means of schematically shown expansion device 5 located in the beam path, so that they irradiate an area 6 with uniform intensity. Of course, it is also possible to use a series of lasers placed side by side instead of the one laser 1, and to use one or more focusing devices instead of the expansion device 5, which focusing devices direct the beams generated by the lasers at the web in such a way that the area 6 is divided into a number of individual sections located side by side. In connection with a covering device these individual sections can then be selectively covered, with the result that, viewed across its width, and when moving in the direction of the arrow 13, the web is partially irradiated, or not irradiated, along its longitudinal dimension, so that a patterned surface change is obtained.

A further form of embodiment shown in FIG. 5 of a device designed in its entirety as 20 is used for finishing an endless web of yarn 9 which, in the form of embodiment shown in FIG. 5, consists of a band of five individual yarns, which are shown only in an exemplified manner. The number of individual yarns depends on the area which the laser can irradiate. The band of the yarns is transported by a conveyor in the direction of the arrow 13 at a certain speed, which is adapted to the desired surface change and to the power of the laser irradiation; the conveyor includes a draw-off device (not shown) and two rollers 4a and 4b. Above and below the yarn web 9 one each laser 7, or 8, respectively, is located, the beams of which are directed by means of an expansion device (not shown) at the web in such a way that the upper laser 7 irradiates an upper yarn area 11, and the lower laser 8 irradiates a lower yarn area 12, which is shown by a dotted line. This type of arrangement assures that, as viewed across the circumference of the yarn, a uniform irradiation of the surface and thus a uniform surface change takes place. In order to prevent a sagging of the yarns and therefore a change in their distance to the upper laser 7 or the lower laser 8, the section between the two rollers 4a and 4b of the version shown in FIG. 5 is considerably shorter as compared with the device shown in FIG. 1 since, as the result of the above-described placement of the lasers, the yarn irradiation device precludes the use of a conveyor belt to support the web.

The following examples have the purpose of clarifying the advantages which are attainable with the invention's process.

EXAMPLE 1

With the use of laboratory equipment a polyester fabric with a weight of 80 g/m^2 and a warp density of 25 threads/cm and a weft density of 35 threads/cm was treated with laser irradiation. The laser used was a KrF-Excimer laser with a wave length of 248 nm, and an area of 2 cm^2 was irradiated with one impulse as well as with ten impulses. The energy of one beam impulse was 400 mJ. In the samples thus irradiated, water absorption was measured gravimetrically after 48 hours of storage in standard climate at 20° C. and 65% relative humidity. The following results were obtained:

Untreated sample: Water absorption 0.5%
Treated sample, 1 beam impulse: Water absorption 4%
Treated sample, 10 beam impulses: Water absorption 7%.

EXAMPLE 2

A polyester fabric with a weight of 100 g/m^2, a warp density of 40 threads/cm and a weft density of 50 threads/cm was irradiated as described in example 1; for this test, an ArF-Excimer laser with a wave length of 193 nm was used. The energy of the beam impulse was 200 mJ. The following water absorption values were obtained:

Untreated sample: Water absorption 0.4%.
Treated sample, one impulse: Water absorption 2.3%
Treated sample, 10 beam impulses: Water absorption 4.9%

With respect to the two preceding examples it should be mentioned that in both cases the sample was treated from one side only with one or ten non-focused beams.

EXAMPLE 3

Of the fabric mentioned in example 1, one each of a section of a non-treated sample, of a sample treated with one beam impulse and of a sample treated with ten beam impulses was printed with pigment. The printing paste contained 280 g bonding agent (200 g Acramin VLC, 30 g Acracone 0, 50 g Acrafix M), 20 g pigment (Acramin Marine Blue FBC), 3 g triethanolamine and 697 g water. After application of the printing paste, drying for one minute at 120° C., and condensing at 170° for three minutes, the adhesion of the print to the fabric was tested with a Crockmeter.

Staining of accompanying cotton fabric as per grey scale after

	50 friction cycles	100 friction cycles	250 friction cycles
untreated sample	2–3		
irradiated sample, 1 beam impulse	3–4	3	2–3
irradiated sample, 10 beam impulses	4	4	3–4

As can be seen in the above table, the adhesion of the pigment print is considerably worse in the untreated sample than in the irradiated samples, as evidenced by the respective grades, particularly after 100 or 250 friction cycles.

As proven by sample 1, the use of the invention's process considerably improves water absorption, particularly in synthetic fibers, so that the clothing which is made with these has excellent physiological properties. This is manifested on the one hand by improved moisture or water absorption, and on the other hand by increased water exchange, so that clothing of this type has the advantages of natural fibers with respect to wearing comfort, as well as the advantages of synthetic fibers with respect to simple care. Furthermore, irradiation according to the invention of fibers, filaments, yarns, flat articles or nonwoven material of synthetic fibers, or containing these yarns, has the result that very unpleasant electrostatic charging occurs not at all or in a very limited way, which is ascribed to the above-described increased water absorption. Thus, the use of the invention's process can achieve in a very simple manner a permanent antistatic finishing of fibers etc., which is extremely interesting, not only for clothing, but also for carpet floors or dust filters.

In addition, the use of the invention's process with fiber bonding substances can considerably increase the adhesion between the matrix into which the fibers are bedded and the fibers themselves, with the result that such fiber bonding substances have considerably improved strength and decreased wear tendencies, and consequently longer service life. The fibers are preferably irradiated immediately after spinning, such at that time, as viewed across its circumference, the fiber is still accessible from all sides and optimal surface roughening can be obtained, which is seen as the cause of the improvement of adhesion between the matrix and the fibers. Generally speaking, such a process should be used particularly with such fibers which have a smooth, non-profiled surface, which applies, for example, to PTFE or Aramid fibers or fiber mixtures.

EXAMPLE 4

Polyester woven goods with a weight 99 g/m^2 and a warp density of 375 threads/dm and a weft density of 340 threads/dm was rinsed with the conventional processes and subsequently fixed at 190° C. The warp threads had 76 individual filaments and a denier of 105 dtex, and the weft threads also had 76 individual filaments, and a denier of 156 dtex.

An area of the above-mentioned polyester fabric was irradiated with two light beam impulses generated by an ArF-Excimer laser; the energy of the light beam impulses was 57 mJ/cm^2 and the wave length was 193 nm. After both beam impulses had been directed at the surface of the area of the polyester fabric, the light beam was moved according to a predetermined geometric pattern in such a way that a section adjacent to this area was also treated with two light beam impulses.

Subsequently the polyester fabric irradiated in this manner was dyed in a laboratory dyeing facility with a bath ratio of 1:15; the dyeing bath had the following composition:

1% C.I. Disperse Blue 79, 200 per cent
0.5 g/l of a deflocculation agent on the basis of a condensation product of aromatic sulfonic acids
0.25 ml/l acetic acid

The coloring substances were premixed in the conventional manner and the dyeing was begun at a starting temperature of 60° C. Subsequently the dyeing bath was heated at 1° C./min to 130° C. After a dwell period of 30 minutes at the above temperature the bath was cooled at 1° C./min to 80° C. There followed an alkaline reductive purification with sodium hydrosulfide in the conventional concentration.

After dyeing and drying the sample was at first visually evaluated. It was apparent that the patterned areas had been dyed in a considerably darker shade. The geometric pattern created by the movement of the light beam was clearly visible and had a sharp outline.

Sections were taken from the irradiated and non-irradiated areas of the polyester fabric, and their dye concentration was determined quantitatively after dissolving the fiber substrate. It was noted that the irradiated sample showed 8% more dye absorption than the non-irradiated sample.

With respect to rubbing-resistance, sweat resistance, bleaching resistance and dry heat bleaching resistance, thre were no differences between the irradiated and non-irradiated areas.

EXAMPLE 5

The above-described polyester fabric was irradiated in a manner analogous to example 4, however, ten light beam impulses with an energy of 85.2 mJ/cm^2 were directed at the selected area of the surface. Subsequently, the light beam was moved according to the predetermined pattern to an adjacent area, and the ten light beams were again emitted.

The sample of the polyester fabric treated in this manner was dyed and retreated as described above.

After dyeing and drying the sample was visually evaluated. It was noted that the irradiated areas were considerably still more deeply or darkly dyed, so that the geometric pattern showed up even more clearly. The subsequent colorimetric evaluation showed that the irradiated areas were dyed 35% more darkly than the non-irradiated areas. The sharpness of the outline of this sample was excellent. It was noted there, too, that there were no differences in the color-fastness.

EXAMPLE 6

A pile floor carpet with a polyamide nub layer of 500 g/m^2 was reoriented by 140° over one edge. The pile nubs which were freely accessible to the light team at the edge were irradiated in selected areas in such a way that the light beam was concentrated on about the upper third of the pile nub and was moved according to a randomly selected pattern. Simultaneously, the pile floor carpet was transported relative to the laser generating the light beam; the speed of the laser movement was 10 cm/min and the transport speed of the pile floor carpet was 5 cm/min. An ArF-Excimer laser was used, and 100 beam impulses were emitted at each irradiated section of the patterned area. The energy of the beam impulses was 100 mJ/cm^2.

By reduction of the upper third of the irradiated pile nubs a three-dimensionally patterned pile floor carpet was created, and the pattern produced in this manner was still clearly visible after intensive mechanical stress.

EXAMPLE 7

A polyester fabric irradiated as in example 5 was dyed after irradiation with the following combination of coloring substances:

0.7% C.I. Disperse Blue 56
0.7% C.I. Disperse Red 1
0.7% C.I. Disperse Yellow 60

The dyeing and the reductive purification was conducted according to example 4.

After dyeing and drying the sample was visually evaluated. It was noted that the dye absorption was clearly higher in the patterned areas produced by irradiation than in the non-irradiated areas; the difference in color shade was estimated at ca. 30 to ca. 40%. In addition there was a color shade difference between irradiated and non-irradiated areas. Thus, the non-irradiated area of the polyester fabric was dyed in an olive-green brown, while the irradiated areas shows a shift in color shade to a considerably fuller, reddish-blue brown.

In addition to the above-described dyeing another dyeing-process was implemented with the same combination of coloring substances, in which the dye bath contained an additional 0.25 g/l of a levelling agent on the basis of a preparation of alkyphenol and fatty-acid polyglycolethers.

The comparison of the dyeings with and without the levelling agent showed that, in the dyeing without the levelling agent, the difference between the irradiated and non-irradiated areas was considerably greater. A deterioration of the above-mentioned resistances in the irradiated areas could not be detected. Comparative tensile strength measurements showed that no difference whatsoever existed between the irradiated and the non-irradiated areas.

EXAMPLE 8

In a laboratory facility a polyester fabric with a weight of 80 g/m^2 and a warp density of 25 threads/cm and a weft density of 32 threads/cm was treated with laser irradiation. The laser used was a KrF-Excimer laser with a wave length of 248 nm; an area of 2 cm^2 was irradiated with one impulse as well as with 10 impulses. The energy of a beam impulse was 400 mJ. The irradiation was conducted in a CO_2 and a SO_2 gas atmosphere.

The water absorption of the samples treated in this manner was measured gravimetrically after 40 hours of storage in standard climate at 20° C. and 65% relative humidity. The following results were obtained:

untreated sample, water absorption: 0.5%
treated sample, 1 beam impulse, CO_2 atmosphere, water absorption: 6%
treated sample, 10 beam impulses, CO_2 atmosphere, water absorption: 8%
treated sample, 1 beam impulse, SO_2 atmosphere, water absorption: 8%
treated sample, 10 beam impulses, SO_2 atmosphere, water absorption: 10%.

A dye test according to Melliand-Textilber, 60 (1979, 272) was used as proof of the acid groups which were formed on certain areas of the surface during irradiation in the acid gas atmosphere.

In the dye test the nonirradiated sample did not accept the dye, while all irradiated samples accepted the

dye with increasing intensity in the sequence CO_2 atmosphere, 1 beam impulse; CO_2 atmosphere, 10 beam impulses; SO_2 atmosphere, 1 beam impulse; SO_2 atmosphere, 10 beam impulses; the dyeing was dotted and linear. This permits the conclusion that acid groups occurred at the surface of the fabric as the result of the irradiation, which acid groups can be ascribed to a splitting of the surface molecules and to reaction with the acid gas.

Furthermore, the surface resistance of all samples was measured with the annular electrode method. The samples had been previously sufficiently conditioned in standard climate (23° C., 65% relative humidity). The following values were obtained:

untreated sample 10^{13} Ohm;
CO_2 atmosphere, 1 beam impulse, 10^{10} Ohm;
CO_2 atmosphere, 10 beam impulses, 10^9 Ohm;
SO_2 atmosphere, 1 beam impulse 10^8 Ohm;
SO_2 atmosphere, 10 beam impulses 10^7 Ohm.

As the above values prove, the fabric which was chemically and physically modified in its surface has clearly improved surface resistances, which is ascribed to the presence of polar groups. Thus, the samples which were irradiated in a reacting gas atmosphere were permanently antistatic without the application of a corresponding finish.

EXAMPLE 9

The polyester fabric described in example 8 was irradiated in a laboratory facility. An ArF-Excimer laser with a wave length of 193 nm was used. The irradiation was conducted in a NH_3 atmosphere. Each sample was treated with one impulse and with ten impulses; the energy of a beam impulse was 200 mJ. Subsequently, one untreated sample and the two irradiated samples were given a two-component polyurethane coating at 80 g/m^2. After drying and condensation the bending-stress durability was measured (Balli-Flexometer), which led to the following results:

	untreated sample	1 beam impulse	10 beam impulse
1. at 20° C. dry	150,000 flexures, slight loosening of coating in the flex area	200,000 flexures, slight loosening of the coating in the flex area	250,000 flexures, no finding
2. at 20° C. wet	130,000 flexures, damage as in 1	180,000 flexures, no finding	250,000 flexures, no finding

As these results show, irradiation treatment in the ammonia atmosphere clearly improves bending stress durability. This is ascribed to the fact that, in addition to the microstructuring, basic groups occur at the surface of the fabric, which react with the acid groups that are present in the polyurethane coating and thus improve the adhesion of the polyurethane coating on the carrier fabric.

We claim:

1. A process for manufacturing a filament, fiber, yarn, and/or textile or nonwoven goods formed therefrom including the step of irradiating the fiber, filament, yarn, textile and/or nonwoven goods with a laser radiation

beam having an energy density in a range of 5 mJ/cm^2 to 500 mJ/cm^2 for heating localized portions of the surface to which the laser radiation beam is applied to melt material of a filament or fiber and/or to thermally remove material from said portions to form a surface microstructure comprising linear depressions and/or elevations on a filament and/or fiber extending primarily transversely with respect to the longitudinal axis of the fiber and/or filament, said depressions and/or elevations having widths up to about 1 micrometer, a spacing between them of about 1 micrometer to 5 micrometers, and a depth or height, respectively, of up to 100 micrometers, said microstructure extending over about 10% to about 100% of the surface of the fiber and/or filament.

2. The process according to claim **1** further defined as carrying out the irradiating with pulses of laser radiation, said pulses having a duration in a range of 10^{-3} to 10^{-15} seconds.

3. The process according to claim **1** further defined as carrying out the irradiating with pulses of laser radiation at pulse rates of between 1 Hz and 250 Hz.

4. The process according to claim **2** further defined as carrying out the irradiating with pulses of laser radiation at pulse rates of between 1 Hz and 250 Hz.

5. The process according to claim **1** further defined as carrying out the irradiating with laser radiation having a wavelength in a range of 5 nm to 1200 nm.

6. The process according to claim **1** further defined as carrying out the irradiating with a gas pulse laser.

7. The process according to claim **6** further defined as carrying out the irradiating with an Excimer laser.

8. The process according to claim **6** further defined as carrying out the irradiating with a KrF or ArF laser and with radiation wavelengths of 248 or 193 nm.

9. The process according to claim **1** further defined as irradiating substantially the entire surface of a filament, fiber and/or yarn.

10. The process according to claim **1** further defined as irradiating at least one side of textile or nonwoven goods.

11. The process according to claim **1** further defined as irradiating textile or nonwoven goods with the laser radiation beam and thereafter applying a coating to the goods.

12. The process according to claim **1** further defined as irradiating textile or nonwoven goods with the laser radiation beam and thereafter printing or dyeing the goods.

13. The process according to claim **1** further defined as one for finishing nonwoven goods used for filtration purposes and wherein the laser beam irradiation occurs during the production of the nonwoven goods.

14. The process according to claim **1** wherein relative movement is provided between the laser radiation beam and the filament, fiber, yarn, and/or textile or nonwoven goods.

15. The process according to claim **10** further defined in that a web of textile or nonwoven goods is continuously moved and is irradiated by a linear laser beam oriented transversely to the direction of the movement of the web.

16. The process according to claim **1** further defined as carrying out the irradiation in a gaseous environment.

17. The process according to claim **1** further defined as carrying out the irradiation in a protective environment.

18. The process according to claim **17** further defined as carrying out the irradiation in an atmosphere of protective gas.

19. The process according to claim **17** further defined as carrying out the irradiation in a vacuum.

20. The process according to claim **1** further defined as carrying out the irradiation in a reactive environment.

21. The process according to claim **20** further defined as carrying out the irradiation in an atmosphere containing at least one reactive gas.

22. The process according to claim **21** further defined as carrying out the irradiation in an atmosphere containing an acidic or basic gas.

23. The process according to claim **21** further defined as carrying out the irradiation in an atmosphere containing a gas having oxygen compounds with carbon, nitrogen and/or sulfur.

24. The process according to claim **21** further defined as carrying out the irradiation in an atmosphere containing a gas having an interhalogen compound and/or a halogen-hydrogen compound.

25. The process according to claim **21** further defined as carrying out the irradiation in an atmosphere containing a gas having at least a double or triple bond.

26. The process according to claim **21** further defined as carrying out the irradiation in an atmosphere containing an inert gas mixed with the reactive gas.

27. The process according to claim **1** further defined as irradiating a thermoplastic fiber.

28. The process according to claim **15** further defined as irradiating a textile of thermoplastic fibers.

29. The process according to claim **21** further defined as irradiating a thermoplastic fiber.

30. The process according to claim **1** further defined as carrying out the irradiating to form lineal depressions and/or elevations which extend over ca. 20% to ca. 80% of the surface of the fiber and/or filament.

31. The process according to claim **30** further defined as carrying out the irradiating to form lineal depressions and/or elevations which extend over ca. 40% to ca. 60% of the surface of the fiber and/or filament.

32. The process according to claim **1** further defined as carrying out the irradiating to form depressions and/or elevations which have a depth or height, respectively, of between ca. 1 micrometer and ca. 4 micrometers.

33. The process according to claim **1** further defined as carrying out the irradiating to form lineal depressions and/or elevations which have a depth or height, respectively, of between ca. 0.1 micrometer and ca. 2 micrometers.

34. The process according to claim **33** further defined as carrying out the irradiating to form lineal depressions and/or elevations which have a depth or height, respectively, of between ca. 0.5 micrometer and ca. 1 micrometer.

35. The process according to claim **1** further defined as carrying out the irradiating to form lineal depressions and/or elevations which have a width up to ca. 0.5 micrometer and a spacing between them of ca. 1 micrometer to 3 micrometers.

36. A filament, fiber, yarn, and/or textile or nonwoven goods formed therefrom produced by the process according to claim **1**.

37. A filament, fiber, yarn, and/or textile or nonwoven goods formed therefrom produced by the process according to claim **15**.

38. A filament, fiber, yarn, and/or textile or nonwoven goods formed therefrom produced by the process according to claim **21**.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,017,423

DATED : May 21, 1991

INVENTOR(S) : Adelgund Bossmann et al

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 19, line 12, delete "100" and substitute therefor ---10---

Column 19, line 35, after "248" insert ---nm---

Signed and Sealed this

Sixteenth Day of March, 1993

Attest:

STEPHEN G. KUNIN

Attesting Officer

Acting Commissioner of Patents and Trademarks

United States Patent [19]

Azuma et al.

[11] Patent Number: 4,861,620

[45] Date of Patent: Aug. 29, 1989

[54] METHOD OF LASER MARKING

[75] Inventors: Kenkoku Azuma; Masaaki Sakaki, both of Nagoya, Japan

[73] Assignee: Mitsubishi Denki Kabushiki Kaisha, Tokyo, Japan

[21] Appl. No.: 111,320

[22] Filed: Oct. 22, 1987

[30] Foreign Application Priority Data

Nov. 14, 1986 [JP] Japan 61-271273
Nov. 20, 1986 [JP] Japan 61-277406

[51] Int. Cl.⁴ B05D 3/06; G01D 9/00

[52] U.S. Cl. 427/53.1; 346/1.1; 346/108; 430/945

[58] Field of Search 427/53.1; 346/1.1, 108; 430/962, 348, 349, 363, 365, 945, 964

[56] References Cited

U.S. PATENT DOCUMENTS

3,761,942 9/1973 Lorenz et al. .... 346/108 X
4,753,863 6/1988 Spanjer .... 430/945 X

FOREIGN PATENT DOCUMENTS

44750 1/1982 European Pat. Off. .
3311882 2/1985 Fed. Rep. of Germany .
155493 8/1985 Japan 430/945
1459799 12/1976 United Kingdom .

Primary Examiner—Michael Lusignan
Attorney, Agent, or Firm—Sughrue, Mion, Zinn, Macpeak & Seas

[57] ABSTRACT

A pigment layer is provided on a surface of an article on which a marking is to be formed and is irradiated with patterned laser light to change internal molecular structure of pigment to thereby change its color. The marking can be multicolored by a suitable selection of pigment and laser energy density.

4 Claims, 3 Drawing Sheets

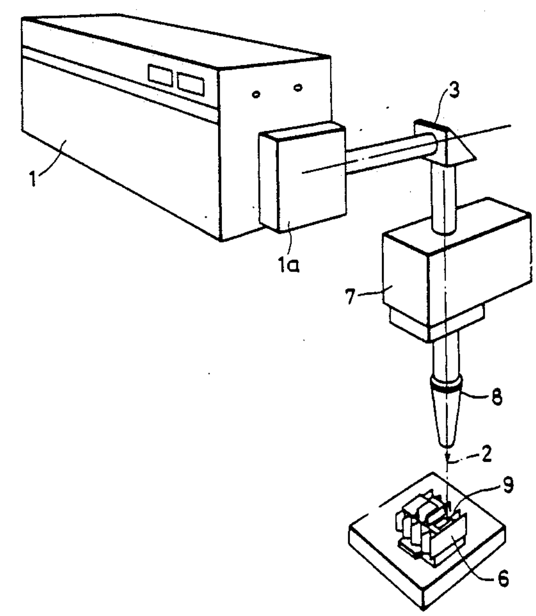


FIG. 1

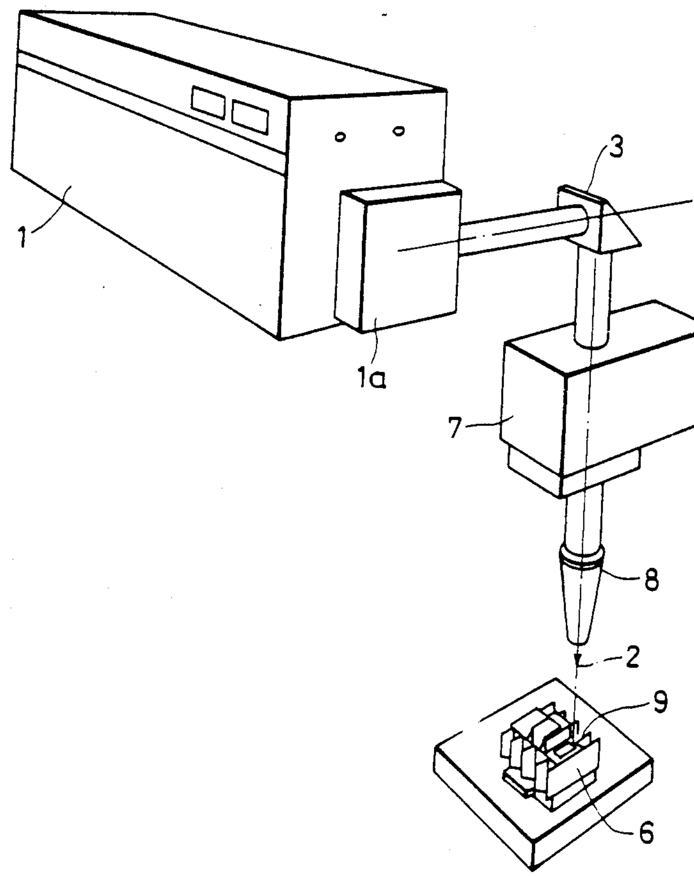


FIG. 2

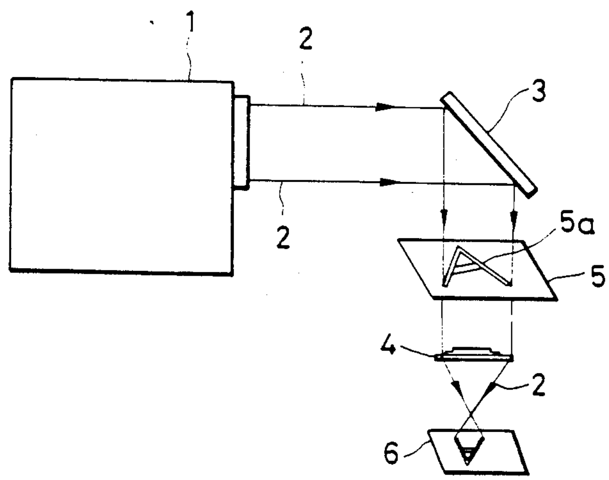


FIG. 3

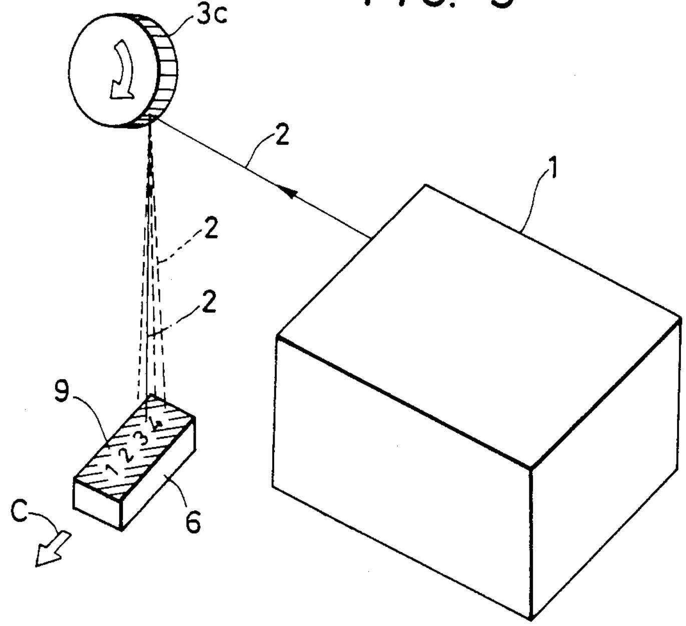
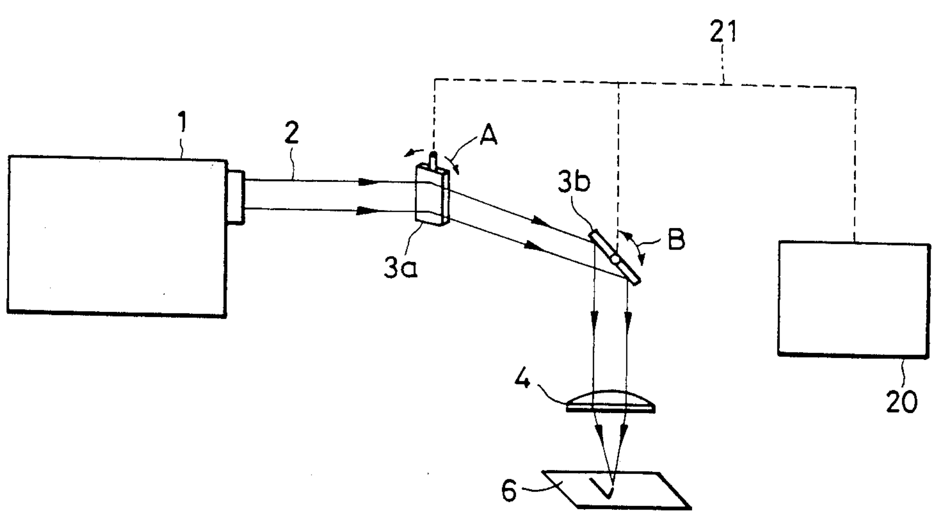


FIG. 4



METHOD OF LASER MARKING

BACKGROUND OF THE INVENTION

The present invention relates to a method of laser marking which is used to form on a surface of an article a sharp mark by means of laser beam at high speed.

In forming marks such as a symbol mark, configuration of product and manufacturing data of product, etc., on a surface of an article, it has been usual to use the so-called mask transfer technique by which a plurality of symbols and/or characters are transferred onto such surface simultaneously at high speed or to engrave the surface up to several microns by scanning a laser beam along symbols and/or character to be marked thereon.

Particularly, in the conventional marking method using a laser beam, a portion of the product on which the marking is to be performed by local laser-heating and evaporation of material of the product must be heated to a temperature at which such local evaporation takes place. The temperature depends upon the material of the product and it is about 500° C. when the material is of plastics and about 2000° C. when the material is ceramics.

Therefore, in order to achieve such high temperature of the local portion of the product, an output power of a laser must be large enough. However, when the product is, for example, an electronic component such as a semiconductor device, there is a strong possibility of thermal degradation thereof due to local heating by the laser beam and dust and/or smoke produced during the laser marking may contaminate the electronic component.

Since the marking is performed by the local evaporation and/or burning of the material, the smoothness of the surface of the product may be degraded and the sharpness of the mark formed thereon may become degraded sometimes.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method of laser marking by which a temperature rise of a product having a surface on which the marking is performed is restricted and a reduction of the required laser power is realized while the sharpness of the mark is acceptable.

Another object of the present invention is to provide a method of laser marking by which a mark to be provided is multicolored so that the mark itself can be easily identified.

According to the present invention, a surface of a product on which the laser marking is performed is coated with a layer of pigment whose color is changed when its temperature exceeds a predetermined value by painting a surface portion of the material or by mixing such pigment into the material of the product and the marking is performed by irradiating the surface with a laser beam along a path defining a desired mark so that the latter mark is provided as a portion of the surface whose color is changed.

Pigment to be used in this invention changes its color by a change of internal structure thereof at or higher than a predetermined temperature. Pigment may be selected from a group consisting of a Hg compound, cobalt compound, iron compound, copper compound, nickel compound, lead compound, vanadium compound and any mixture thereof.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a perspective view of an apparatus for performing the present method;

FIG. **2** illustrates an operation of the apparatus shown in FIG. **1**;

FIG. **3** is a perspective view of another apparatus for performing the present method;

FIG. **4** is a further apparatus for performing the present method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIGS. **1** and **2**, in which FIG. **1** is a perspective view of a TEACO2 laser marking apparatus suitable for the mask transfer technique and FIG. **2** illustrates an operation of the marking apparatus shown in FIG. **1**, a reference numeral **1** depicts a laser oscillator for transmitting a marking laser beam **2**. The laser beam **2** is directed to a reflection mirror **3** from which it is directed to a condenser lens **4**. The beams condensed by the condenser lens **4** is passed through a mask **5** having a marking pattern **5***a* to a surface of a product **6** on which the marking pattern **5***a*, in this illustration, a letter A, is formed.

A shutter **1***a* is provided in a laser path between the laser oscillator **1** and the reflection mirror **3** and the mask **5** is housed in a mask holder **7**. The condenser lens **4** is housed in a condenser portion **8**. The product **6** to be marked is shown in this figure as an electro-magnetic switch and a portion thereof on which the mark is to be provided is shown by a reference numeral **9**.

Describing the present method in more detail, the marking portion **9** of the source of the product **6** is preliminarily coated with a layer of pigment whose color is changed by its internal structure at or higher than a predetermined temperature. The coating can be acievied by painting the portion with the pigment. Alternatively, it may be possible to mix the pigment into the material of the product and thereafter to mold the latter. The latter method may be useful when the product is of plastic material.

Then, the positional relation between the laser oscillator **1**, the reflection mirror **3**, the mask plate **5**, the condenser lens **4** and the product **6** is regulated such that the surface of the product **6** on the side of the condenser lens **4** is faced to the mask plate **5**. Then, the surface portion **9** of the product **6** is irradiated with the laser beam **2** from the laser oscillator **1** through the mask plate **5** having the marking pattern **5***a* and the condenser lens **4**. With this irradiation, pigment in the portion irradiated with the laser beam is heated thereby to the predetermined temperature or higher immediately and changes its internal structure and hence its color, resulting in a mark having a different color from its background color.

As to an irreversible or semi-irreversible change of internal structure and hence color of the pigment due to a temperature increase by the laser irradiation, there are two types, one being pigment whose molecules such as H_2O and CO_2 etc. are discharged therefrom by the heating at or higher than the predetermined temperature so that it is thermally decomposed to change the molecular structure permanently to thereby provide a different color from its original color and the other being pigment whose crystalline structure and hence color is changed by such as glass transition due to the increased temperature.

A classification of pigments used in embodiments are given in Table 1 and temperatures at which the pigments in Table 1 change their colors and the colors changes are given in Table 2. In Table 2, other temperatures and color changes than typical are also given for reference. It should be noted that the embodiments numbered 6 to 20 are color changes due to thermal decomposition.

TABLE 1

Embodiments	classification of pigments
No. 1	Hg (inorg.) compound
2	
3	
4	
5	
6	cobalt compound (e.g., cobalt oxalate including water of crystallization, cobalt formate including water of crystallization, cobalt phosphate including water of crystallization)
7	potassium cobalticnitride
8	copper compound
9	cobalt compound
10	cobalt compound
11	bismuth oxalate
12	copper oxalate
13	cobalt compound
14	cobalt oxalate
15	nickel oxalate + cobalt oxalate
16	nickel compound
17	lead compound
18	
19	
20	

TABLE 2

Embodiments	original color	color change temp.	new color	note	
No. 1	light pink	50° C.	light blue		semi-irreversible
2	light pink	70	light blue tinted violet		semi-irreversible
3	light pink	80	light violet		semi-irreversible
4	light pink	90	light violet		semi-irreversible
5	light green	110	light blue tinted violet	yellow tinted gray at about 70° C.	semi-irreversible
6	light purple red	130	blue violet		irreversible
7	blue tinted green	140	light violet		irreversible
8	light green tinted blue	160	gray black		irreversible
9	purple red	180	brown black		irreversible
10	light yellow orange	200	light blue tinted violet		irreversible
11	white	220	gray black	light pink at about 180° C.	irreversible
12	light green tinted blue	250	red tinted gray	brown black at about 270° C.	irreversible

TABLE 2-continued

Embodiments	original color	color change temp.	new color	note	
13	light yellow orange	270	light blue violet		irreversible
14	light pink	290	black	light brown at about 170° C.	irreversible
15	light blue tinted gray	310	brown black		irreversible
16	light blue green	330	gray black		irreversible
17	white	360	orange	gray white at about 290° C.	irreversible
18	blue	410	brown white		irreversible
19	white	440	light yellow brown	blue tinted white at about 210° C. blue tinted black at about 310° C.	irreversible
20	violet	450	white		irreversible

The inventors have conducted various experiments on each of the embodiments listed in Tables 1 and 2 and those conducted on the embodiment No. 6 will be described in detail as an example.

In the experiments conducted on the embodiment No. 6, the pigment used was a paint containing powder of $Co_3(PO_4)\ 8H_2O$, particle size being 2 μm or smaller, and having the following constituents:

$CO_3(PO_4)8H_2O$	30 wt %
tarc	4 wt %
ethylcellose lacquer	33 wt %
(resin component	15 wt %)
thinner	33 wt %

A surface of a phenol resin plate of 5 mm thick which was used as an example of the product was sprayed with the above mentioned paint to form a pigment layer of about 30 μm thick thereon. The phenol resin plate having the pigment layer was dried at room temperature for about 24 hours. The resultant product was irradiated with a short pulse laser beam of pulse width of 1 μm or narrower from the $TEACO_2$ laser oscillator **1** shown in FIG. **1** and color changes of portions of the surface thereof were observed. When the energy density of the laser beam at the pigment layer was 1.0 Joule/cm^2, the original pink color of the pigment layer was changed to a blue color uniformly and 16 numerals of alternate gothic type each being 1.2 mm tall (at transfer time) punched in a copper plate mask disposed in the mask holding portion **7** were sharply transferred onto the pigment layer. When the energy density of the laser beam was 0.6 Joule/cm^2 or smaller, there were incomplete local color changes produced in each numeral and a reading of the transferred numerals became difficult. It is believed that the observed color change is due to the phenomenon that a portion of eight water molecules

in cobalt phosphate is made free by the laser irradiation and it is changed to another cobalt phosphate including an unknown amount of water which exhibits blue color and is expressed by ($Co_3(PO_4)_2\ XH_2O$ ($1<X<7$)), according to the following reaction:

$$\underset{\text{(pink)}}{Co_3(PO_4)_2\ 8H_2O} \xrightarrow[\text{irradiation}]{\text{laser}} \underset{\text{(blue)}}{Co_3(PO_4)_2\ XH_2O} + (8\text{-}X)H_2O$$

The assumption of the range of X is due to the fact that cobalt phosphate having no water of crystallization exhibits red color.

For a comparison purpose, identical phenol resin plates to the plate used in the above experiments and having no pigment coating were irradiated with laser beams from the same apparatus as that used in the above experiments, with the laser energy density being varied to find the critical laser energy density necessary to clearly read out the numerals transferred onto the pigment layer. According to the latter experiments, the critical energy density was 4 Joule/cm^2 and it was possible to read out the numerals clearly when the energy density was more than the critical value at which the numerals transferred onto the black pigment layer were exhibited by gray white and which were not clear with respect to the black background.

Other embodiments which employ iron compounds as the pigments and which are not shown in Table 1 are represented by the following reaction formula:

$$\alpha\text{-FeOOH(yellow)} \xrightarrow[200^\circ \text{ C.}]{\text{laser irradiation}} \alpha\text{-}Fe_2O_3 \text{ (red)}$$

$$\gamma\text{-}Fe_2O_3 \text{ (brown)} \xrightarrow[530^\circ \text{ C.}]{\text{laser irradiation}} \alpha\text{-}Fe_2O_3 \text{ (red)}$$

As mentioned hereinbefore, the laser marking method according to the present invention utilizes the change in internal structure of the pigment by a temperature increase thereof due to laser beam irradiation. Therefore, there are no problems of dust and/or smoke which are undesirable for the product to be marked and the mark itself is formed without engraving on the product surface. The contrast of the mark with respect to the background can be made very high.

Depending upon the kind of pigment, it is possible to restrict the temperature at which the color change occurs to a relatively low value, e.g., 70° C. and therefore the present marking can be performed even for the product which is thermally unstable. Further, as mentioned previously, the laser power to be used in this invention can be remarkably reduced compared with the conventional method which uses the local evaporation or burning of material forming the product.

FIG. **3** is a perspective view of a laser marking apparatus of a laser dot impact marking type which is composed of a combination of a pulse laser and a polygonal mirror and FIG. **4** shows a modification of the apparatus in FIG. **3**, in which the the polygonal mirrors is replaced by a pair of scanning mirror **3***a* swingeable in a direction A and a scanning mirror B swingable in a direction B are provided and are program-controlled by control signals **21** from a controller **20**.

In FIG. **3**, the polygonal mirror **3***c* is rotated while the product **6** to be marked is moved in a direction C so that the product **6** is scanned in a direction orthogonal to the direction C.

With the apparatus shown in FIGS. **3** and **4**, the present method can be effectively performed. While the

TEACO$_2$ laser is described herein as the source of the laser beam, other lasers, such as an Nd:YAG laser, can be also used for this invention with the same effect.

In another experiment, pigment having the following constituents was used, with which a plate which is identical to the phenol plate used in the previously mentioned experiment was spray-coated to a thickness of about 30 μm and, after being dried at room temperature for about 24 hours, the plate was subjected to laser irradiation in the same way as in the previous experiment:

ammonium metavanadate(NH_4VO_3): 25 wt%
tarc: 4 wt%
ethylcellose lacquer: 33 wt%
(resin component: 15 wt%)
thinner: 38 wt%

It was observed that, when energy density of a short pulse laser, pulse width being 1 μm or narrower, from the TEACO$_2$ laser **1** is from 1.1 Joule to 1.8 Joule/cm^2, the original color, white, was changed to brown uniformly and **16** alternate gothic numerals punched in the copper mask **5** were clearly transferred. When laser energy density was 0.8 Joule/cm^2 or smaller, transferred numerals were locally faded causing the reading thereof to be difficult. It is believed that the color change is realized due to the phenomenon that water molecules and ammonia molecules are discharged from ammonium metavanadate according to the following reaction, resulting in vanadium pentoxide:

$$\underset{\text{(white)}}{2NH_4VO_3} \xrightarrow[\text{irradiation}]{\text{laser}} \underset{\text{(brown)}}{V_2O_5} + H_2O + 2NH_3$$

With the laser energy density increased from 1.8 Joule/cm^2 to 5.0 Joule/cm^2, the original white color was changed to black uniformly. Thus it is possible to provide a multi-colored marking by selecting pigment and laser energy density suitably.

Another experiment was conducted by using nickel chloride hexamethylene-tetramine ($NiCl_2 2C_6H_{12}N_4 10\text{-}H_2O$) as pigment with the following composition:

nickel chloride hexamethylene-tetramine: 25 wt%
tarc: 5 wt%
ethylcellose lacquer: 40 wt%
thinner: 30 wt%

An aluminum plate was coated with a layer of pigment, about 30 μm thick, and, after being dried under the same conditions as those used in the previous experiment, a portion thereof was irradiated for 1.5 m sec. with CO$_2$ gas laser energy density of 250 W/cm^2. With this laser irradiation, the original color, green, was changed to yellow green. Another portion of the pigment layer was irradiated for 3.0 m sec. with a laser energy density of 250 W/cm^2. The color of the latter portion was changed from its original green color to light blue violet. It is believed that this color change is due to discharge of water of crystallization as shown in the following reactions:

$$\underset{\text{(green)}}{NiCl_2.2C_6H_{12}N_4.10H_2O} \xrightarrow{\text{laser irradiation(1.5 msec.)}} \underset{\text{(yellow green)}}{NiCl_2.2C_6H_{12}N_4.2H_2O} + 8H_2O$$

-continued

$$\underset{\text{(green)}}{NiCl_2.2C_6H_{12}N_4.10H_2O} \xrightarrow{\text{laser irradiation(3.0 msec)}} NiCl_2.2C_6H_{12}N_4 + 10\ H_2O$$

Thus it is possible to provide a multi-colored marking.

As mentioned herein before, it is possible, according to the present invention, to provide a mono-colored or multi-colored marking by a suitable selection of pigment and laser energy density.

What is claimed is:

1. A method of marking an article surface comprising the steps of

coating the article surface with pigment or mixing the pigment into the material of the article, wherein said pigment is capable of changing its original color to another color at or higher than a predetermined temperature, and

irradiating portions of the pigment coating with a marking laser light, whereby the irradiated portions are marked by the another color,

wherein said pigment is a combination of a plurality of different pigments providing different colors at different temperatures, respectively, and said marking laser is a mixture of a corresponding number of laser beams having different energy densities necessary to heat said article surface to said different temperatures, respectively, whereby said irradiated portions of said article surface are marked with said different colors.

2. The method as claimed in claim **1**, wherein said pigment contains material capable of changing its original color to another color by a change of its internal molecular structure caused by heat given by said laser light.

3. The method as claimed in claim **2**, wherein said pigment is selected from a group consisting of Hg compound, cobalt compound, potassium cobaltienitride, copper compound, nickel compound, lead compound, iron compound, vanadium compound and any mixture thereof.

4. The method as claimed in claim **1**, wherein said portions of said pigment layer are irradiated with laser light of different energy density, respectively.

* * * * *

EXHIBIT 5

US005567207A

United States Patent [19]

Lockman et al.

[11] Patent Number: 5,567,207

[45] Date of Patent: Oct. 22, 1996

[54] **METHOD FOR MARKING AND FADING TEXTILES WITH LASERS**

[75] Inventors: **William J. Lockman**, Longwood; **Frank J. Clayson**, Apopka, both of Fla.

[73] Assignee: **Icon, Inc.**, Apopka, Fla.

[21] Appl. No.: **274,473**

[22] Filed: **Jul. 31, 1994**

[51] **Int. Cl.**[6] **D06P 5/20**

[52] **U.S. Cl.** **8/444**; 8/115.52; 8/115.53

[58] **Field of Search** 8/444, 115.52, 8/13

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,847,184	7/1989	Taniguchi et al.	430/346
4,861,620	8/1989	Azuma et al.	427/53.1
4,901,089	2/1990	Bricot	366/76 L
5,017,423	5/1991	Bossmann et al.	428/224
5,248,878	9/1993	Ihara	219/121

FOREIGN PATENT DOCUMENTS

3916126	5/1989	Germany .
5-278237	10/1993	Japan .

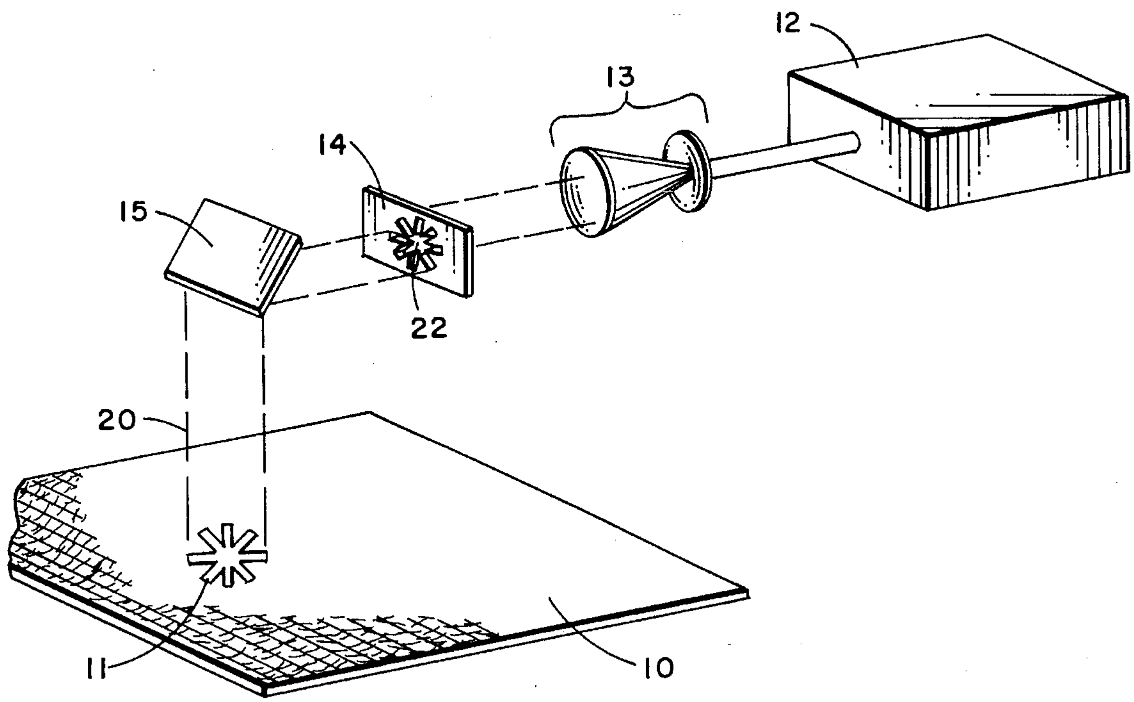
Primary Examiner—Margaret Ensman

Attorney, Agent, or Firm—Maguire, Voorhis & Wells, P.A.

[57] **ABSTRACT**

The present invention relates to an environmentally safe, water-free method for color fading and for producing patterns on textile materials (**1, 10**) by exposure to laser radiation (**7, 12**) of sufficient intensity to cause photo-decomposition of the coloring agent while leaving the underlying textile material undamaged. The pre-dyed material (**1, 10**), such as denim, is scanned by a laser beam (**19, 20**) generated by a selected laser having selective output characteristics to produce uniform fading and patterns of photo-bleached marks on the textile material (**1, 10**). When the laser radiation is modulated at a selected frequency, the fading may take the form of stone washing (**18*a*** and **18*b***), echo ball washing, or acid washing techniques commonly used on denim materials. The patterns (**17*a*** and **17*b***) may take the form of any desired image, line, or picture in the substrate material. For mass production the textile materials may be moved under the laser by a conveyer belt or similar means.

33 Claims, 2 Drawing Sheets



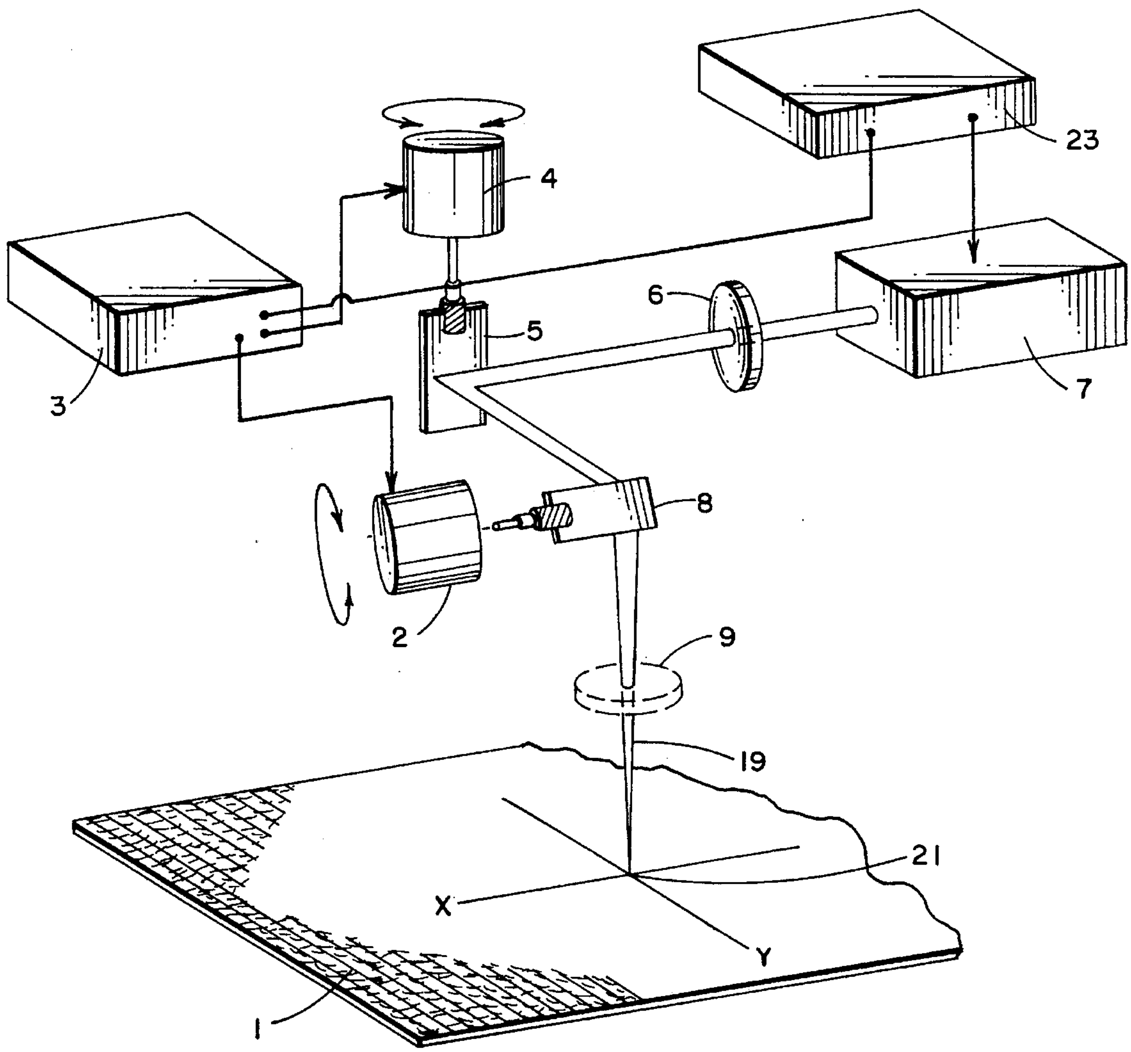


FIG. 1

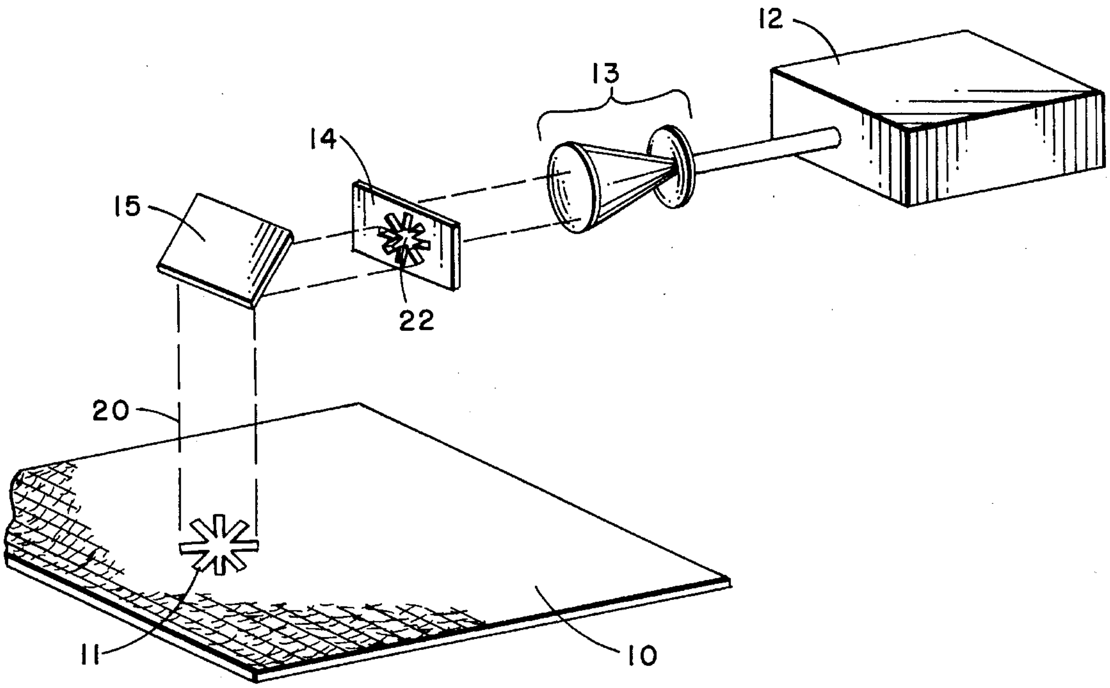


FIG. 2

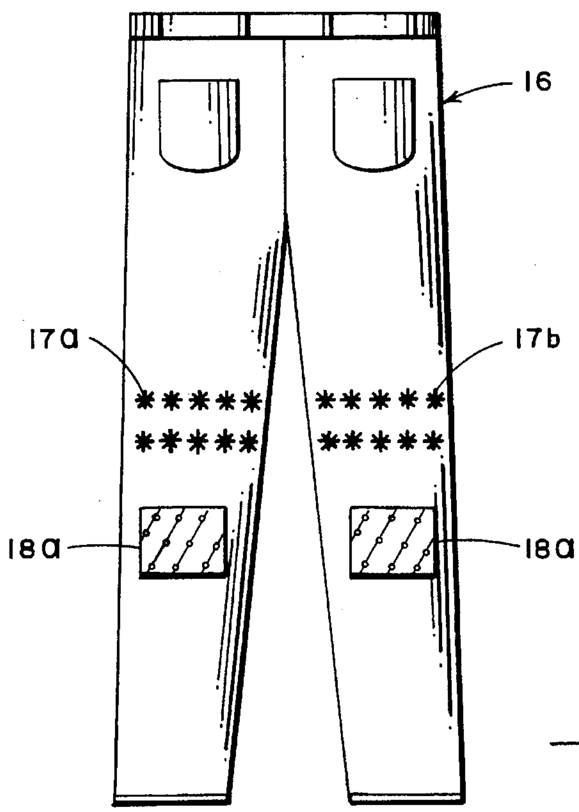


FIG. 3

METHOD FOR MARKING AND FADING TEXTILES WITH LASERS

BACKGROUND OF THE INVENTION

This invention relates to methods of uniform color fading, fading with patterns and marking patterns onto textiles materials, such as denim, using lasers. More particularly, it relates to using lasers to simulate conventional laundering techniques, such as stone washing, echo ball washing and acid washing without the use of water or chemicals. Still more particularly, it relates to performing the above mentioned process in an environmentally safe manner.

It is known that laser beams are used to record patterns in various materials. The great heat available when the laser beam is focused to a small spot can be used to change the physical properties of a material. In previous methods, the visible change in the material properties are produced by burning, charring, melting or other severe modifications of the physical characteristics of the material.

The present invention describes a method where intense laser radiation is directed onto a pre-dyed textile material such as denim. The laser parameters such as wavelength, average power, pulse duration, power density, and scan speed are adjusted to provide efficient absorption into the dye components of the textile material. The absorption of the laser radiation by the dye components results in rapid and selective photo-decomposition of the dye elements. The result of controlled exposure is a color fading or color removal effect.

Vapors and debris resulting from the rapid photo-decomposition of the dye elements in the textile material can be easily removed from the work environment by standard suction and filtration machinery now used in many industrial applications. In the industrial environment, this method is best applied on a moving web of textile material. In the case of broad coverage, the laser beam is scanned across the material in a direction perpendicular to the direction of the textile. The laser beam scan rate, power density, average power, pulse width, and repetition rate are synchronized to the speed of the textile material such that the desired fading pattern is created.

Currently, fading of textile materials, such as denim, is accomplished on finished clothing articles by a multi-stage laundering process that utilizes conventional washing machines, large quantities of water, and various chemical and mechanical additives that act on the fabric to produce the desired fading effects. Stone wash methods use actual stones or rocks in the washing process. These stones impact the denim material and result in the desired fading pattern. A variation of this method uses golf balls in place of stones in the washing process. This "Echo Ball" washing technique results in a similar pattern to that of stone watching. Another method of fading finished denim clothing is with the use of chemicals in an aqueous mixture containing alkaline or chlorine that causes a uniform fading of the colored textile material. More recent developments have included using enzymes or other bacteriological agents in the fading process.

Large amounts of water are used in the previous stone washing, echo ball washing, and acid washing fading methods. As much as 15 gallons of water is used per clothing article in these processes. At current annual production rates, the textile industry uses six billion gallons of water per year in the U.S. for denim finishing operations. Moreover, the water used in these processes is contaminated with dyes and

other chemicals and often requires purification before being discharged. When purification is not required by law, the contaminated waste water is discharged into the environment.

All previous methods perform the fading process on textile materials that have been cut and sewn to form completed clothing article. This is the most practical method available today since conventional finishing methods are performed in industrial washing machines. Significant improvements could be realized in the manufacturing process if a method could be found to perform the fading operation on the material prior to it being cut and sewn into finished garment form.

Fading denim material after it is cut and sewn into finished garments adds time, labor, resources and costs to the finishing process. Thus, a need exists for uniformly fading and fading with patterns textile materials such as denim without the use of water or harsh chemicals. A need also exists for a method of fading and marking textile materials prior to assembly into finished garments.

Currently, marking detailed patterns on colored textile fabric, such as denim, is accomplished by methods similar to laser printers where dye is made to adhere to specific areas of a drum mechanism exposed to laser radiation. The drum with dye components is rolled across wet textile material to transfer the pattern. Other methods include applying heat to a film placed on the fabric.

Still other methods include the use of laser radiation to heat the textile to allow for better adhesion by the dyes. The prior patented art includes some methods for using a laser to mark various items, including textiles, but most require the use of wet dye solutions and none is like the present invention.

U.S. Pat. No. 4,861,620 by Azuma, et al., issued Aug. 29, 1989, describes a method of laser marking which requires that a pigment coating be placed on the surface of the article being marked. Then a focused laser beam is used to affect the internal molecular structure of the pigment to change color. U.S. Pat. No. 4,901,089 by Bricot, issued Feb. 13, 1990, discloses a method and device for the recording of pictures by laser which requires several layers of material be placed on a substrate. A laser beam is used to ablate the top material to form an image. U.S. Pat. No. 4,847,184 by Taniguchi, et al., issued Jul. 11, 1989, teaches a method for transferring a still video image onto a substrate that is carbonizeable or discolorable. Unlike the present invention, this technique engraves a pattern into the substrate to form a pattern of some depth. U.S. Pat. No. 5,017,423 by Bossmann, et at., issued May 21, 1991, teaches a process for manufacturing textile materials using lasers. In this method, a laser beam is used to cause a physical change in the textile material. This change, due to charring and burning effects, results in a larger cross-sectional area being exposed to the dyeing process. The larger cross section of the textile results in better dye adhesiveness. U.S. Pat. No. 5,248,878 by Ihara, issued Sep. 28, 1993, concerns marking golf balls using lasers. Finally, German Patent No. 39 16 126, involves using a laser beam to print a pattern on textile fabrics that is wet with dye. This latter method creates a pattern on the material by changing the color of the dye. Thus, a need exists for a method for marking various detailed patterns on colored textile fabrics without damaging the fabrics.

Unlike the above patents, the present invention uses an environmentally safe method for marking, fading and treating textile fabrics with a laser without the need for conventional washing methods, wet dyes, or excessive amounts of water.

SUMMARY OF THE INVENTION

The primary object of the present invention is to provide an improved and environmentally safe, water free method for uniformly fading and fading with patterns various textile materials, including finished colored denim, using a laser.

Another object of the present invention is to provide an environmentally safe, water free process for producing stone washing and acid washing effects on various textile materials, including finished colored denim, with lasers.

Another object of the present invention is to provide a method for marking patterns and images on various textile materials, including finished colored denim, using a laser.

Another object of the present invention is to provide such a method that does not damage the textile material on which it is used.

Another object of the present invention is to provide such a method that does not require the use of chemicals or acids.

The present invention fulfills the above and other objects by providing a method for color fading and producing patterns on textile materials with a laser by placing under the laser a pre-dyed textile material and then scanning a laser beam having a selected wavelength, power density, pulse width, and repetition rate over the textile material until the desired degree of fading or the selected pattern is achieved. The laser would preferably be a q-switched Nd:YAG laser with a wavelength of about 1064 nanometers, although other lasers, such as CO_2 gas lasers or Excimer gas lasers may be utilized. The wavelength of the laser is chosen to give optimal dye photo-decomposition without affecting the textile material.

The scanning of the laser beam over the textile material may be controlled by galvanometric mirror, acousto-optic deflector, deflector, magneto-optic beam deflector, polygon mirror, or a moving holographic optical element. The textile material may be made of natural, synthetic, woven, knit, or pressed fiber textile materials.

The patterns which would be made of a series of lines and/or dots may take the form of images, text, or pictures on the textile material.

These and other objects, advantages, and features of the present invention will become even more readily apparent when the preferred embodiments are discussed in conjunction with drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawing figures used in conjunction with the description of the preferred embodiments are as follows:

FIG. **1** is a perspective schematic view of a typical set up using the present invention involving a computer-controlled laser to uniformly fade or make patterns;

FIG. **2** is a perspective view of a mask set up to produce patterns using a laser; and

FIG. **3** is a frontal view of dungarees made using this method showing selected patterns made by a laser.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the accompanying drawings, the present invention is described in more detail.

In FIG. **1**, which is the simplified block diagram of the textile marking apparatus, the scanning mirrors and the laser parameters such as output power and repetition rate are set by the laser controller **23** and a Central Processing Unit (CPU) **3**. The parameters for the desired pattern to be made on the textile **1** is programmed into the CPU **3**. The beam position and laser intensity are rapidly modulated to produce the desired stone wash effects.

The CPU **3** has graphic information and formatted instructions to drive the galvanometric mirrors and control the laser parameters in order to produce the desired pattern on the textile material. As per the command sequence, a q-switched laser beam **19** originates from a laser oscillator **7**. The laser oscillator **7** may be a Nd:YAG laser or other laser source, q-switched with an acousto-optic or electro-optic modulator. The laser beam may follow an optical system (not shown for clarity) that directs the beam onto an x-axis mirror **5** controlled by an x-axis galvanometer **4** and a y-axis mirror **8** controlled by an y-axis galvanometer **2**. The beam is reflected from the x-axis mirror, which controls beam movement in the x-axis, onto the y-axis mirror, which controls beam movements in the y-axis. The laser beam propagates through the focusing lens **6** and onto the textile material. The focusing lens can be located before or after the x and y scanning mirrors. As the x-axis and y-axis mirrors are moved, the focused laser beam **21** moves across the textile substrate as directed by the CPU **3**.

Using the present invention broadly could achieve a stone-wash appearance on a textile or jeans with much less water use or damage to the textile material than that which occurs through actual stone washing.

A second embodiment of this invention is illustrated in FIG. **2**. Although the method illustrated in FIG. **1**, which utilizes a computer **3** to control the operation is a typical set up, the second embodiment shown in FIG. **2** uses a mask instead to project an entire image or pattern **11** on the textile **10**. In this embodiment the laser **12** projects a laser beam into a beam expander **13** which consists of two lenses similar to a telescope. The expanded beam is then projected through a mask **14** containing an aperture **22** in the shape of the desired pattern **11** to be projected on the textile **10**. The patterned laser beam **22** is then reflected off a mirror **15** directly onto the textile **10** for a predetermined period in order to form the desired pattern **11** on the textile **10**.

The final illustration, FIG. **3**, shows a pair of denim jeans **16** which has been subjected to this method for laser marking and treatment of textile materials. On the jeans **16** are shown two different patterns, one being a design pattern **17*a*** and **17*b***, which is made with a series of lines, such as that which would be made with either the set up illustrated in FIG. **1** or the set up in FIG. **2**. It is contemplated that this inventive process may be implemented in the manufacture of textile material prior to being cut into clothing forms, and during the transport of such uncut material on a conveyor belt during the manufacturing process.

This type of pattern would more likely result from the set up illustrated in FIG. **1**. A second type of pattern that is shown is the stone wash pattern of **18*a*** and **18*b***. This type of pattern would also result for the set up illustrated in FIG. **1**. Depending on the intensity of the beam and the time it is allowed to remain on the textile, the patterns illustrated in FIG. **3** could be the result of selective photo-decomposition resulting in a white or faded appearance where the pattern is located on the denim. The inventors have conducted numerous experiments to test their method, arriving at various parameters for use of the method. All experiments to date have been done using the Nd:YAG laser with a wavelength of around 1064 nanometers. The laser beam may be generated by a frequency doubled Nd:YAG laser having a wavelength of approximately 532 nm.

Other possible wavelengths for other laser sources range between 190 nanometers to 10600 nanometers. An Excimer laser may operate effectively at wavelengths 196 nm to 235 nm, or a CO laser may operate effectively at 10600 nanometers. The wavelength of the laser should be chosen such that it is strongly absorbed by the dye to be faded but not by the textile material. The range of pulse duration used has been from 5 nanoseconds to 100 microseconds, with the best results being from 20 to 350 nanoseconds. Other variables, such as the pulse energy, peak power, scan speed, dot pitch, and energy density play an important factor in the degree of photo-decomposition and the avoidance of damage to the textile material.

For example, these variable parameters may include the laser beam having a repetition rate from 1 hertz to 500 MHz (500×10^6 hertz), a pulse duration between approximately 10 fs (10×10^{-15} seconds) to 500 ms (500×10^{-3} seconds), the laser beam may have a continuous output beam and is classified as a cw laser, or the laser beam have a scan speed of 1 mm per minute to 500 meter/second, and a dot pitch between 0.1 um to 5 meters.

Although only the preferred embodiments of this invention have been described in detail hereinabove, it is intended that all variations and modifications of this invention within the scope of the claims are covered by this invention.

Having thus described our invention, we claim:

1. A method for color fading, dyed textile materials with a laser, comprising the steps of:

placing under a laser beam a dyed textile material; and

scanning the laser beam generated by the laser with a selected set of parameters to fade the dye of the textile material to replicate a uniformly faded textile or a stone washed, acid washed or acid ball washed textile.

2. The method of claim **1** wherein the textile material is denim and the parameters are chosen so the laser beam fades the dye on the textile material to replicate the look of a stone washed denim.

3. The method of claim **1** wherein the textile material is denim and the parameters are chosen so the laser beam fades the dye on the textile material to replicate a uniformly faded denim.

4. The method of claim **1** wherein the textile material is a denim and the parameters are chosen so the laser beam fades the dye on the textile material to replicate a look of acid washed denim.

5. The method of claim **1** wherein the textile material is a denim and the parameters are chosen so the laser beam fades the dye on the textile material to replicate a look of echo ball washed denim.

6. The method of claim **1** wherein the laser beam is generated by a Nd:YAG laser having a wavelength of approximately 1064 nm.

7. The method of claim **1** wherein the laser beam is generated by a frequency doubled Nd:YAG laser having a wavelength of approximately 532 nm.

8. The method of claim **1** wherein the laser beam is generated by a CO_2 gas laser having a wavelength of approximately 10600 nm.

9. The method of claim **1** wherein the laser beam is generated by a Excimer laser having a wavelength from approximately 196 nm to 235 nm.

10. The method of claim **1** wherein placing the textile material under the laser beam is accomplished by use of a conveyer belt on which the textile material is placed.

11. The method of claim **1** wherein the laser beam has a repetition rate from 1 hertz to 500 MHz (500×10^6 hertz.)

12. The method of claim **1** wherein the laser beam has a pulse duration between approximately 10 fs (10×10^{-15} seconds) to 500 ms (500×10^{-3} seconds).

13. The method of claim **1** wherein the laser beam has a continuous output beam and is classified as a cw laser.

14. The method of claim **1** wherein the laser beam is scanned across the textile material at a rate between approximately 1 mm per minute to 500 meters per second.

15. The method of claim **1** wherein the dot pitch of the laser beam is between approximately 0.1 um to 5 meters.

16. The method of claim **1** wherein the scanning of the laser beam is carried out by a galvanometric controlled mirror.

17. The method of claim **1** wherein the scanning of the laser beam is carried out by an acousto-optic beam deflector.

18. The method of claim **1** wherein the scanning of the laser beam is carried out by an electro-optic beam deflector.

19. The method of claim **1** wherein the scanning of the laser beam is carried out by an magneto-optic beam deflector.

20. The method of claim **1** wherein the scanning of the laser beam is carried out by a polygon mirror.

21. The method of claim **1** where in the scanning of the laser beam is carried out by a moving holographic optical element.

22. The method of claim **1** wherein the textile material is made of denim.

23. The method of claim **1** wherein the textile material is made of woven textile.

24. The method of claim **1** wherein the textile material is made of any natural, synthetic, blended, woven, knit or pressed fiber textile material.

25. The method of claim **1** wherein the laser beam is scanned across the uncut web of textile material.

26. The method of claim **1** wherein the laser beam is scanned across completed garments.

27. A method for fading textile materials treated with a dye, comprising the steps of:

(a) providing a source of laser radiation; and,

(b) irradiating the textile material with a laser beam scanned under preselected parameters for absorption by the dye to uniformly fade said dye.

28. The method of claim **27** wherein the laser beam is generated by a Nd:YAG laser having a wavelength of approximately 1064 nm.

29. The method of claim **27** wherein the laser beam has a repetition rate from 1 hertz to 500 MHz (500 c 10^6 hertz).

30. The method of claim **27** wherein the laser beam has a pulse duration between approximately 10 fs (10×10^{-15} seconds) to 500 ms (200×10^{-3} seconds).

31. The method of claim **27** wherein the laser beam has a continuous output beam and is classified as a cw laser.

32. The method of claim **27** wherein the laser beam is scanned across the textile material at a rate between approximately 1 mm per minute to 500 meters per second.

33. The method of claim **27** wherein the dot pitch of the laser beam is between approximately 0.1 um to 5 meters.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
Certificate

Patent No. 5,567,207 Patented: October 22, 1996

On petition requesting issuance of a certificate for correction of inventorship pursuant to 35 U.S.C. 256, it has been found that the above identified patent, through error and without any deceptive intent, improperly sets forth the inventorship.

Accordingly, it is hereby certified that the correct inventorship of this patent is: William J. Lockman, Longwood, FL; Frank J. Clayson, Apopka, FL; and Wayne K. Shaffer, Apopka, FL.

Signed and Sealed this First Day of March 2005.

YOGENDRA N. GUPTA
Supervisory Patent Examiner
Art Unit 1751

EXHIBIT 6

СОЮЗ СОВЕТСКИХ СОЦИАЛИСТИЧЕСКИХ РЕСПУБЛИК

ГОСУДАРСТВЕННЫЙ КОМИТЕТ ПО ИЗОБРЕТЕНИЯМ И ОТКРЫТИЯМ

ПРИ ГОСУДАРСТВЕННОМ КОМИТЕТЕ СССР ПО НАУКЕ И ТЕХНИКЕ

(ГОСКОМИЗОБРЕТЕНИЙ)

АВТОРСКОЕ СВИДЕТЕЛЬСТВО

№ 1559794

На основании полномочий, предоставленных Правительством СССР, Госкомизобретений выдал настоящее авторское свидетельство на изобретение:
"Способ образования узоров на длинномерном материале"

Автор (авторы): Григорян Жорик Седракович, Шевелева Лариса Вольфовна, Давиденко Владимир Владимирович, ~~Смеречинская~~ Нина Радионовна и Добровольская Анна Ивановна

Заявитель: УКРАИНСКИЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ ТЕКСТИЛЬНОЙ ПРОМЫШЛЕННОСТИ

Заявка № 4439481

Приоритет изобретения 7 мая 1988г.

Зарегистрировано в Государственном реестре изобретений СССР

22 декабря 1989г.

Действие авторского свидетельства распространяется на всю территорию Союза ССР.

Председатель Комитета

Начальник отдела

МПФ Гознака. 1988. Зак. 3083.

ДЛЯ С[redacted]ЕБНОГО [redacted]ЛЬЗОВАНИЯ ЭКЗ. №

СОЮЗ СОВЕТСКИХ СОЦИАЛИСТИЧЕСКИХ РЕСПУБЛИК

(19) SU (11) 1559794 A1

(51)5 D 06 C 23/02

ГОСУДАРСТВЕННЫЙ КОМИТЕТ ПО ИЗОБРЕТЕНИЯМ И ОТКРЫТИЯМ ПРИ ГКНТ СССР

ОПИСАНИЕ ИЗОБРЕТЕНИЯ

К АВТОРСКОМУ СВИДЕТЕЛЬСТВУ

1 2

(21) 4439481/30-12
(22) 07.05.88
(71) Украинский научно-исследовательский институт текстильной промышленности
(72) Ж.С.Григорян, Л.В.Шевелева, В.В.Давиденко, Н.Р.Смеречинская и А.И.Добровольская
(53) 677.634.9 (088.8)
(56) Патент Англии № 1341114, кл. D 06 C 23/00, 1973.
(54) СПОСОБ ОБРАЗОВАНИЯ УЗОРОВ НА ДЛИННОМЕРНОМ МАТЕРИАЛЕ

(57) Изобретение относится к технологическим процессам текстильного, швейного и кожевенного производств и может быть использовано для образования рельефного или колористического узора на поверхности текстильных материалов из натуральных и химических волокон и кож, и позволяет расширить технологические возможности получения узоров на тканях и коже при сохранении их физико-механических свойств путем воздействия на обрабатываемый, предварительно увлажненный материал, лазерным излучением CO_2-лазера непрерывного действия с мощностью излучения 10-100 Вт, длиной волны 10,6 Мкм и скоростью перемещения материала 0,01-1 м/с. 2 табл.

(19) SU (11) 1559794 A1

Изобретение относится к технологическим процессам текстильного, швейного и кожевенного производств и может быть использовано для образования рельефного или колористического узора на поверхности текстильных материалов из натуральных и химических волокон, а также на поверхности кожи.

Цель изобретения - расширение технологических возможностей.

Способ образования узоров на движущемся длинномерном материале, преимущественно текстильном или коже, состоит в том, что материал белый или окрашенный увлажняют до содержания остаточной влаги не более 40 - 50%. Затем на подготовленный материал наносят узор путем воздействия излучения CO_2-лазера с мощностью излучения 10-100 вт и длиной волны 10,6 мкм.

15-90

При нанесении узора происходит или частичное разрушение поверхностного слоя обрабатываемого материала и образуется рельефный узор, или модификация адсорбированного на поверхности материала красителя с изменением его цвета, при этом получают цветовой узор в месте воздействия лазерного луча.

После нанесения узора, в зависимости от обрабатываемого материала, для удаления разрушившихся частиц поверхностного слоя материала в месте воздействия лазерного луча осуществляют следующие операции: механическую очистку, промывку в воде без текстильно-вспомогательных средств и сушку.

Предварительное увлажнение обрабатываемого материала способствует получению более четкого узора, поскольку из-за конечной теплопроводности обрабатываемого образца лазерное излучение распространяется на больший участок по сравнению с тем, на который оно падает. В результате увлажнения теплопроводность образца уменьшается, что ограничивает область распространения теплового лазерного воздействия за пределы заданного контура и обеспечивает его более четкие границы.

Режимы лазерного воздействия, мощность, длина волны излучения, относительная скорость перемещения лазерного луча и обрабатываемого продукта выбраны из соображений получения необходимого эффекта. Так, уменьшение мощности излучения лазера ниже 10 Вт или увеличение относительной скорости перемещения выше 1 м/с не приведет к получению эффекта видимого узора. А увеличение мощности лазерного излучения выше 100 Вт и уменьшение скорости относительного перемещения до 0,1 м/с приведет к полной деструкции продукта.

Использование CO_2-лазера при длине волны 10,6 мкм обеспечивает необходимое воздействие на большинство материалов, в том числе и органических, кроме того, является наиболее экономически выгодным, имеет надежную конструкцию и обладает сроком службы, достаточным для его промышленного применения.

При остаточной влажности менее 40% конечная теплопроводность обрабатываемого образца практически не изменяется, а, следовательно, лазерное излучение распространяется на больший участок по сравнению с тем, на который оно падает. При остаточной влажности более 50% масса образцов увеличивается, что затрудняет их перемещение, а при автоматизации необходимо вводить еще один показатель, влияющий на качество узора. Кроме того, увеличивается испарение жидкости, что ухудшает микроклимат и затрудняет работу обслуживающего персонала.

Все эксперименты проводились при влажности испытуемых образцов 45±5%.

Изобретение иллюстрируется примерами.

Пример 1. Рисунок наносится на предварительно увлажненный образец ткани из ацетатного шелка, окрашенного дисперсным красителем (до содержания остаточной влаги 40-50%). Вода для увлажнения образца подается по трубопроводу и распыляется серийно выпускаемыми форсунками, применяемыми, например в ткацком производстве для доувлажнения воздуха.

Нанесение рисунка производится несфокусированным лучом CO_2-лазера непрерывного действия. Мощность лазерного излучения 5-130 Вт, расстояние от излучателя до образца 0,5 м, скорость перемещения образца 0,01 - 1,3 м/с, тип лазера - ИЛГН - 704.

После нанесения рисунка разрушившийся поверхностный слой удаляют при промывке проточной водой (10 мин) с последующей сушкой в сушильном шкафу при 100°С.

Пример 1а (базовый). Образец ацетатной ткани, окрашенной дисперсным красителем, печатали (сетчатым шаблоном) печатной краской следующего состава, г/кг:

едкий натр (100%-ный)	- 20
загустка присулан SF (4%-ная)	- 700
вода	до 1000.

Затем сушка при 50-80°С, запаривание при 102-104°С в течение 5-7 мин.

Промывка по режиму:

промывка проточной водой	- 10 мин
мыловка 1-я при Т 80°С составом, г/л:	- 10 мин
гидросульфит 1 г/л	
едкий натр 1 г/л	
ТМС 1 г/л	
промывка при Т 80°С	- 10 мин
мыловка 2-я при Т 80°С составом, г/л:	- 10 мин
сода кальценированная	- 1
ТМС	- 0,5
промывка проточной водой	- 5 мин
промывка при Т 80°С	- 10 мин.

Результаты испытаний физико-механических свойств материала приведены в табл.1.

Качество готовых образцов оценивается показателями устойчивости окрасок и физико-механических свойств ткани. Результаты приводятся в табл.1.

Пример 2. На предварительно увлажненное, как в примере 1, трикотажное полотн (полиамид 100%), окра-

шенное и напечатанное дисперсными красителями сфокусированным лучом CO_2-лазера непрерывного действия, наносили произвольный рисунок. Параметры технологического процесса при этом следующие:

мощность лазерного излучения	5 - 130 Вт
расстояние от излучателя до полотна	- 0,08 м
скорость перемещения полотна	- 0,01 - 1,3 м/с

Затем производили механическую очистку: обработку материала в среде насыщенного пара в течение 30 с, а затем чистку щеткой 4-6 прохода.

П р и м е р 2а (базовый). Образец трикотажного полиамидного полотна, окрашенного и напечатанного дисперсными красителями, обрабатывали как в базовом примере 1а.

Результаты испытаний физико-механических свойств полотна и прочности окраски приведены в табл.1.

П р и м е р 3. На предварительно увлажненный, как в примере 1, образец вискозного нетканого полотна, окрашенного прямыми светопрочными красителями сфокусированным лучом CO_2-лазера непрерывного действия, наносили произвольный рисунок. Параметры технологического процесса следующие:

мощность лазерного излучения	5 - 130 Вт
расстояние от излучения до образца	- 0,08 м
скорость перемещения образца	- 0,01 - 1,3 м/с.

Затем механическая очистка, как в примере 2.

П р и м е р 3 а (базовый). Образец вискозного нетканого полотна, окрашенного прямыми светопрочными красителями, обрабатывали, как в базовом примере 1а. Результаты физико-механических свойств материала приведены в табл.1.

П р и м е р 4. Сфокусированным лучом CO_2-лазера непрерывного действия на образец натуральной свиной кожи (лицевая сторона), окрашенной кисл тным красителем для кожи, наносили произвольный рисунок. Параметры процесса при этом следующие:

мощность излучения	5 - 130 Вт
расстояние от излучения до образца	- 0,08 м
скорость перемещения образца	0,01 - 1,3 м/с.

Затем механическая очистка (2 - 4 прохода), как в примере 2.

П р и м е р 4а (базовый). Образец натуральный свиной кожи (лицевая сторона) окрашенной кислотным красителем, обрабатывали, как в базовом примере 1а. Результаты испытаний физико-механических свойств материала приведены в табл.1.

П р и м е р 5. На образец предварительно смоченной, как в примере 1, отбеленной х-б ткани с поверхностной плотностью 197-10 г/м^3 наносится произвольный рисунок несфокусированным лучом CO_2-лазера непрерывного действия. Параметры технологического процесса в данном примере следующие:

мощность излучения	- 5 - 130 Вт
расстояние от излучения до образца	₱ 0,4 м
скорость перемещения образца	0,01 - 1,3 м/с

После нанесения рисунка разрушившееся волокно удаляют при промывке проточной водой (10 мин) с последующей сушкой или механическим способом (щеткой).

П р и м е р 5а (базовый). На образец отбеленной х/б ткани с помощью шаблона наносят состав, содержащий:

бисульфат натрия	- 150
глицерин	- 25
загуститель (индалка) 3%-ный	- 600
вода	до 1000.

Затем высушивают, запаривают в течение 5-7 мин при 160°С.

После этого, для удаления разрушившегося волокна, следует промывка. (М.в. 1 - 30)

проточная вода	- 10 мин
мыловка ТМС - 2 г/л при Т 80°С	- 10 мин
промывка при Т 60°С	- 10 мин
промывка проточной водой	- 10 мин.

Результаты оценки физико-механических свойств готов г образца приведены в табл.2.

П р и м е р 6. Нетканое обувное полотно (опытный образец-лен 100%-ный) с поверхностной плотностью 220 г/м^2, предварительно увлажненное, как в примере 1, для получения произвольного рисунка обработали сфокусированным лучом CO_2-лазера непрерывного действия. Технологические параметры процесса следующие:

мощность излучения	5 - 130 Вт
расстояние от излучателя до полотна	0,08 м
скорость перемещения полотна	0,01 - 1,3 м/с

Затем механическая очистка, как в примере 2.

П р и м е р 6а (базовый). Образец нетканого обувного полотна обрабатывали, как в базовом примере 5а. Результаты физико-механических свойств представлены в табл.2.

П р и м е р 7. На предварительно увлажненный, как в примере 1, образец трикотажного полотна из окрашенной пряжи (поливинилхлорид 12,5%, лавсан 87,6%) с поверхностной плотностью 300 г/м^5 лучом CO_2-лазера непрерывного действия наносили произвольный рисунок. Технологические параметры обработки образца лучом лазера соответствуют примеру 2. Затем следует промывка, как в примере 1.

П р и м е р 7а (базовый). Образец трикотажного полотна из окрашенной пряжи обрабатывали, как в базовом примере 5а. Результаты оценки готового образца приведены в табл.2.

П р и м е р 8. Предварительно увлажненный, как в примере 1, образец шерстяного драпа (арт. 36460) с поверхностной плотностью 500 г/м^2, обрабатывали для получения на нем произвольного рисунка несфокусированным лучом CO_2-лазера непрерывного действия.

Параметры технологического процесса следующие:

мощность излучения	5 - 130 Вт
расстояние от излучателя до образца	0,4 м
скорость перемещения образца	0,01 - 1,3 м/с

Последующая очистка, как в примере 2.

П р и м е р 8а (базовый). На образец шерстяного драпа (арт.36460) с помощью шаблона наносят состав, содержащий:

едкий натр	- 200
загуститель (индалка) 3%-ный	- 600
вода до	- 1000

Затем сушка, запаривание в течение 5-7 мин при 160°С. После этого для удаления разрушившегося волокна следует промывка:

(М-в 1:30)

проточная вода - 10 мин

мыловка ТМС-2 г/л при Т 80°С

промывка при - Т 60°С

промывка проточной водой - 10 мин.

Результаты оценки физико-механических свойств образца представлены в табл.2.

П р и м е р 9. На предварительно увлажненный образец п/ш драпа (арт. 4646, шерсть 62%, вискоза 23%, капрон 15%) с поверхностной плотностью 480 г/м^2 наносится произвольный рисунок лучом CO_2-лазера непрерывного действия. Технологические параметры обработки образца лучем лазера соответствуют примеру 9. Последующая обработка, как в примере 1.

П р и м е р 9а (базовый). Образец п/ш драпа (арт.4646) с помощью шаблона наносят состав, содержащий:

едкий натр	- 200
загуститель индалка (3%-ная)	- 600
вода	до - 1000

Затем сушка, запаривание в течение 5 - 7 мин, при 160°С. После этого, для удаления разрушившегося волокна, следует промывка:

(М.в. 1:30)

проточная вода - 10 мин.

мыловка ТМС (2 г/л) при 80°С - 10 мин.

промывка при 60°С - 10 мин.

промывка проточной водой - 10 мин.

Результаты оценки физико-механических свойств образца представлены в табл.2.

Как следует из результатов испытаний физико-механических свойств обрабатываемых материалов, приведенных в табл.2, способ обеспечивает как хорошее качество, так устойчивость окрасок образцов с узором, нанесенным по данному способу, выше на 0,5-1 балла по сравнению с базовым вариантом, а прочностные показатели при получении коло-

ристического узора лучше на 15-20%, а при получении рельефного рисунка - до 50%.

Способ образования узора является экономичным, экологически чистым. При его использовании уменьшается расход воды, пара, электроэнергии, химикатов. Сокращается не менее трех технологических операций, повышается производительность труда и оборудования. Исключение из процесса операций, связанных с использованием химикатов и удалением незафиксированного красителя и препаратов резерва или вытравки, позволяет исключить строительство очистных сооружений. Способ не требует дополнительных специально оборудованных производственных площадей и поэтому может быть применен непосредственно на швейных или обувных предприятиях, а следовательно, узор может быть нанесен на готовое изделие.

Формула изобретения

Способ образования узоров на длинномерном материале путем теплового воздействия на материал на заданных участках с последующей обработкой, отличающийся тем, что, с целью расширения технологических возможностей, перед тепловым воздействием материал увлажняют до содержания остаточной влаги 45-50%, при этом тепловое воздействие осуществляют излучением CO_2-лазера с мощностью излучения 10-100 Вт и длиной волны 10,6 мкм.

Таблица 1

Физико-механические показатели материалов с колористическим узором

Вид обработки образца	Режим обработки: Мощность облучения, Вт	Режим обработки: Относительная скорость перемещения, м/с	Устойчивость окраски в баллах, К: к мылу при кипячении	дист. воде	к трению: сухому	к трению: мокрому	Разрывная нагрузка полоски ткани размером 50х200 мм, Н: основа	уток	Удлинение при разрыве полоски ткани размером 50 х 200 мм, %: основа	уток
									Пример 1	
Без отделки лазерная	-	-	-	-	-	-	232,4	229,7	15,2	16,9
	5	0,01	-	-	-	-	232,4	229,7	15,2	16,9
	10	0,1	5	5	5	5	232,4	229,7	15,2	16,9
	50	0,5	5	5	5	5	231,2	229,5	15,1	16,9
	100	1	5	5	5	5	231,0	229,5	15,0	16,8
	130	1,3	5	5	5-4	5-4	230,7	229,5	14,9	16,8
Пример 1а (базовый)	-	-	5	5-4	4	4	2[illegible]0,9	229,1	14,9	16,7
									Пример 2	
Без отделки лазерная	-	-	-	-	-	-	256,8			19,8
	5	0,01	-	-	-	-	256,8			19,8
	10	0,1	5	5	5	5	256,8			19,8
	50	0,5	5	5	5	5	256,6			19,7
	100	1	5	5	5	5	256,6			19,6
	130	1,3	5	5-4	5-4	4	256,3			19,4
Пример 2а (базовый)	-	-	5	4	4	4	251,4			19,2
									Пример 3	
							по длине	по ширине	по длине	по ширине
Без отделки лазерная	-	-	-	-	-	-	210,2	208,7	18,7	19,2
	5	0,01	-	-	-	-	210,1	208,7	18,7	19,2
	10	0,1	5	5	5	5	210,0	208,5	18,7	19,0
	50	0,5	5	5	5	5	209,5	208,1	18,5	18,9
	100	1	5	5	5	5	209,1	207,8	18,4	18,9
	130	1,3	5	5-4	5-4	4	209,1	207,5	18,5	18,8
Пример 3а (базовый)	-	-	5	4	5-4	4	208,9	207,4	18,2	18,0
									Пример 4	
Без отделки лазерная	-	-	-	-	-	-	1,4		35	
	5	0,01	-	-	-	-	1,4		35	
	10	0,1	-	-	5	5	1,4		35	
	50	0,5	-	-	5	5	1,4		35	
	100	1	-	-	5	5	1,4		35	
	130	1,3	-	-	5	5-4	1,4		35	
Пример 4а (базовый)	-	-	-	-	4	4-3	1,4			

Таблица 2

Физико-механические показатели материалов с рельефным рисунком

Вид обработки образца	Показатели работы лазера: Мощность излучения, Вт	Показатели работы лазера: Относительная скорость перемещения, м/с	Разрывная нагрузка полоски ткани размером 50x200 мм, Н: основа	Разрывная нагрузка полоски ткани размером 50x200 мм, Н: уток	Удлинение при разрыве полоски ткани размером 50 x 200 мм, %: основа	Удлинение при разрыве полоски ткани размером 50 x 200 мм, %: уток
Пример 5						
Без отделки	-	-	332,5	330,3	16,6	17,1
лазерная	5	0,01	332,0	330,2	16,3	16,8
	10	0,1	330,7	329,6	16,0	16,6
	50	0,5	329,2	327,8	15,9	16,1
	100	1	327,9	325,7	15,7	15,9
	130	1,3	222,5	221,2	14,1	14,9
Пример 5а (базовый)	-	-	195,1	191,4	5,4	5,8
Пример 6						
Без отделки	-	-	497,6	495,3	17,5	18,0
лазерная	5	0,01	491,3	489,5	17,5	18,0
	10	0,1	491,0	488,7	17,5	17,9
	50	0,5	490,7	485,3	17,3	17,9
	100	1	489,2	481,5	17,0	17,7
	130	1,3	350,2	245,1	14,8	15,0
Пример 6а (базовый)	-	-	245,7	192,4	6,9	7,2
Пример 7						
Без отделки	-	-	458,7		22,5	
лазерная	5	0,01	458,0		22,5	
	10	0,1	456,3		22,5	
	50	0,5	455,5		22,4	
	100	1	452,9		22,3	
	130	1,3	349,2		18,5	
Пример 7а (базовый)	-	-	215,4		15,1	
Без отделки	-	-	248,8	192,1	17,2	17,3
лазерная	5	0,01	248,0	191,5	17,2	17,2
	10	0,1	247,7	191,2	17,1	17,1
	50	0,5	247,4	190,9	17,0	17,0
	100	1	247,0	190,1	17,0	17,0
	130	1,3	115,9	105,5	14,8	15,0
Пример 8а (базовый)	-	-	111,2	46,4	5,7	5,2
Пример 9						
Без отделки	-	-	347,1	217,7	25,2	26,7
лазерная	5	0,01	347,0	217,5	25,2	26,5
	10	0,1	346,8	216,4	25,0	26,0
	50	0,5	346,3	215,7	25,0	25,7
	100	1	346,1	214,9	24,9	25,5
	130	1,3	295,1	214,9	19,5	19,7
Пример 9а (базовый)	-	-	212,3	115,1	13,8	14,0

Составитель А.Романова
Редактор Н.Козлова Техред М.Ходанич Корректор Л.Бескид

Заказ 908/ДСП Тираж 172 Подписное
ВНИИПИ Государственного комитета по изобретениям и открытиям при ГКНТ СССР
113035, Москва, Ж-35, Раушская наб., д. 4/5

Производственно-издательский комбинат "Патент", г.Ужгород, ул. Гагарина,101

ОТМЕТКА О ВЫПЛАТЕ ВОЗНАГРАЖДЕНИЯ

№№ п/п.	Наименование предприятия, организации, объединения, министерства, ведомства, выплативших вознаграждение	Период, за который выплачивается вознаграждение	Общая сумма вознаграждения за изобретение	Сумма вознаграждения, начисленная автору (ф., и., о.)*)	Подпись уполномоченного лица и дата
1	2	3	4	5	6
1					
2					
3					
4					
5					
6					

*) Сумма единовременного поощрительного вознаграждения, выплаченная автору, подлежит удержанию при выплате вознаграждения за использование изобретения.

(1)

[Cover Page]

UNION OF SOVIET SOCIALIST REPUBLICS

STATE COMMITTEE FOR INVENTIONS AND DISCOVERIES
of the USSR State Committee for Science and Technology
(GOSKOMIZOBRETENIY)

INVENTOR'S CERTIFICATE
No. 1,559,794

Based on the powers invested by the Government of the USSR, Goskomizobreteniy has issued the present inventor's certificate for the invention:

"Method of Making Patterns on Long Material"

Inventor(s): Zhorik Sedrakovich Grigoryan, Larisa Vol'fovna Sheveleva, Vladimir Vladimirovich Davidenko, Nina Radionovna Smerechinskaya, and Anna Ivanovna Dobrovol'skaya

Applicant: UKRAINIAN SCIENTIFIC RESEARCH INSTITUTE OF THE TEXTILE INDUSTRY

Application No. 4439481

Priority of Invention
May 7, 1988

Recorded in the USSR State Register of Inventions

December 22, 1989

This inventor's certificate is valid throughout the USSR.

Committee Chairman [signature]

Department Head [signature]

Union of Soviet Socialist Republics

(19) SU (11) 1,559,794 A1

(51) Int. Cl.[5]: D 06 C 23/02

State Committee for Inventions and Discoveries of the USSR State Committee for Science and Technology

DESCRIPTION OF INVENTION FOR INVENTOR'S CERTIFICATE

(21) Application No.: 4439481/30-12
(22) Application Date: 5/7/88
(71) Applicant: Ukrainian Scientific Research Institute of the Textile Industry
(72) Inventors: Zh. S. Grigoryan, L. V. Sheveleva, V. V. Davidenko, N. R. Smerechinskaya, and A. I. Dobrovol'skaya
(53) UDC: 677.634.9 (088.8)
(56) Other Patent Publications Taken Into Consideration: British Patent No. 1,341,114, Cl. D 06 C 23/00, 1973.

(54) Title of the Invention: METHOD OF MAKING PATTERNS ON LONG MATERIAL

(57) Abstract:

The invention pertains to manufacturing processes for textile, garment, and leather production. It can be used to make a three-dimensional or colored pattern on the surface of textile materials made of natural or synthetic fibers or leathers, and makes it possible to expand the technological capabilities for obtaining patterns on fabrics and leathers without degrading the physico-mechanical properties thereof. The premoistened work material moving at a speed of 0.01-1 m/s is exposed to the radiation of a continuous-wave CO_2 laser with an output power of 10-100 W and a wavelength of 10.6 μm.

2 tables.

The invention pertains to manufacturing processes for textile, garment, and leather production, and can be used to make a three-dimensional or colored pattern on the surface of textile materials made of natural or synthetic fibers, as well as on the surface of leather.

The object of the invention is to expand the technological capabilities.

The method of making patterns on long, moving materials, primarily textiles or leather, consists of moistening the white or dyed material to a residual moisture content of not more than 40-50%. Then the pattern is applied by exposing this prepared

material to the radiation of a CO_2 laser with an output power of 10-100 W and a wavelength of 10.6 µm.

The pattern is formed either by the partial disintegration of the work-material surface layer to form a three-dimensional pattern or by the modification of the dye adsorbed on the material surface, causing a color change and thus producing a colored pattern in the areas exposed to the laser radiation.

After the pattern is applied, depending on the work material, the following operations are performed to remove the disintegrated particles of the material surface layer from the areas exposed to laser radiation: mechanical cleaning, rinsing in water without auxiliary agents, and drying.

Preliminary moistening of the work material helps to obtain a sharper pattern, because the material has appreciable thermal conductivity, which allows the laser radiation to spread from the area of direct exposure. Moistening lowers the thermal conductivity of the material, which limits the spread of the laser heat beyond the intended contour and produces sharper boundaries.

The exposure conditions, including the laser output power, the radiation wavelength, and the relative travel speeds of the laser beam and the work material, were chosen so as to obtain the required results. For example, no visible pattern is obtained if the laser output power is less than 10 W or if the relative travel speed is greater than 1 m/s. Conversely, the material is completely destroyed if the laser output power is greater than 100 W or if the relative travel speed is less than 0.1 m/s.

A CO_2 laser with a wavelength of 10.6 µm produces the required effect on most materials, including organic materials. In addition, this type of laser is economical and reliable, and has sufficient service life for industrial use.

At residual moisture contents below 40%, the thermal conductivity of the work material is appreciable and practically constant, and thus the laser radiation spreads beyond the area of direct exposure. At residual moisture contents above 50%, the weight of the material increases, which hinders movement of the material and requires that another parameter affecting pattern quality be taken into account for automation. In addition, there is increased evaporation, which degrades the microclimate and makes the operators' work more difficult.

All the test specimens in the experiments had a moisture content of 45±5%.

The invention is illustrated by the following examples.

Example 1. A design was applied to a premoistened specimen of acetate rayon fabric dyed with a disperse dye (to a residual moisture content of 40-50%). The water for moistening the specimen was delivered by a pipe and sprayed through standard nozzles of the type used, for example, for air humidification in textile production.

The design was applied using the unfocused beam of an ILGN-704 continuous-wave CO_2 laser. The laser output power was 5-130 W, the distance between the laser and the specimen was 0.5 m, and the specimen travel speed was 0.01-1.3 m/s.

After the design was applied, the disintegrated surface layer was removed by rinsing in flowing water (10 min) and drying in a desiccating cabinet at 100°C.

Example 1a (Reference). A specimen of acetate fabric dyed with a disperse dye was screen-printed using a printing dye of the following composition, g/kg:

caustic soda (100%)	20
prisulan SF thickening agent (4%)	700
water	up to 1000

The specimen then was dried at 50-80°C and steamed at 102-104°C for 5-7 min.

The specimen was rinsed as follows:

rinsing in flowing water		10 min
first soaping at T 80°C		10 min
using a composition of, g/liter:		
hydrosulfite	1 g/liter	
caustic soda	1 g/liter	
TMS	1 g/liter	
rinsing at T 80°C		10 min
second soaping at T 80°C		10 min
using a composition of, g/liter:		
soda ash	1	
TMS	0.5	
rinsing in flowing water		5 min
rinsing at T 80°C		10 min

The test results for the physico-mechanical properties of the material are shown in Table 1.

The quality of the finished specimens was evaluated based on the colorfastness and the physico-mechanical properties of the fabric. The results are shown in Table 1.

Example 2. A random design was applied using a continuous-wave CO_2 laser to a knit fabric (100% polyamide) that had been dyed and printed with disperse dyes and premoistened as in Example 1. The process parameters were:

laser output power	5-130 W
distance between laser and fabric	0.08 m
fabric travel speed	0.01-1.3 m/s

The fabric then was mechanically cleaned by treating it in saturated steam for 30 s and cleaning it with 4-6 brushings.

Example 2a (Reference). A specimen of knit polyamide fabric dyed and printed with disperse dyes was processed in the same manner as Reference Example 1a.

The test results for the physico-mechanical properties and colorfastness are shown in Table 1.

Example 3. A random design was applied using the focused beam of a continuous-wave CO_2 laser to a specimen of unwoven rayon fabric that had been dyed with lightfast direct dyes and premoistened as in Example 1. The process parameters were:

laser output power	5-130 W
distance between laser and specimen	0.08 m
specimen travel speed	0.01-1.3 m/s

The fabric then was mechanically cleaned as in Example 2.

Example 3a (Reference). A specimen of unwoven rayon fabric dyed with lightfast direct dyes was processed in the same manner as Reference Example 1a. The test results for the physico-mechanical properties are shown in Table 1.

Example 4. A random design was applied using the focused beam of a continuous-wave CO_2 laser to a specimen of natural pigskin leather (grain side) dyed with an acid leather dye. The process parameters were:

laser output power	5-130 W
distance between laser and specimen	0.08 m
specimen travel speed	0.01-1.3 m/s

The fabric then was mechanically cleaned (2-4 brushings) as in Example 2.

Example 4a (Reference). A specimen of natural pigskin leather (grain side) dyed with an acid dye was processed in the same manner as Reference Example 1a. The test results for the physico-mechanical properties of the material are shown in Table 1.

Example 5. A random design was applied using the unfocused beam of a continuous-wave CO_2 laser to a specimen of bleached cotton fabric with a surface density of 197-10 g/m^3 and premoistened as in Example 1. The process parameters in this example were:

laser output power	5-130 W
distance between laser and specimen	0.4 m
specimen travel speed	0.01-1.3 m/s

After the pattern was applied, the disintegrated fibers were removed by rinsing in flowing water (10 min) and drying or by mechanical cleaning (brushing).

Example 5a (Reference). A specimen of bleached cotton fabric was screen-printed with a compound containing:

sodium bisulfate	150
glycerin	25
thickening agent (indalka) 3%	600
water	up to 1000.

Then the specimen was dried and steamed for 5-7 min at 160°C.

After this, the specimen was rinsed to remove the disintegrated fibers.

(M.v. 1-30)

flowing water	10 min
soaping TMS 2 g/liter	
at T 80°C	10 min
rinsing at T 60°C	10 min
rinsing in flowing water	10 min

The test results for the physico-mechanical properties of the finished specimen are shown in Table 2.

Example 6. A nonwoven footwear fabric (an experimental specimen of 100% linen) with a surface density of 220 g/m^2 and premoistened as in Example 1 was processed with the focused beam of a continuous-wave CO_2 laser to obtain a random design. The process parameters were:

laser output power	5-130 W
distance between laser and fabric	0.08 m
fabric travel speed	0.01-1.3 m/s

The fabric then was mechanically cleaned as in Example 2.

Example 6a (Reference). A specimen of nonwoven footwear fabric was processed as described in Reference Example 5a. The test results for the physico-mechanical properties are shown in Table 2.

Example 7. A random design was applied using the beam of a continuous-wave CO_2 laser to a specimen of knit fabric made of dyed yarn (12.5% polyvinylchloride, 87.6% lavsan) with a surface density of 300 g/m^2 and premoistened as in Example 1. The process parameters for the laser treatment were the same as in Example 2. The fabric then was rinsed as in Example 1.

Example 7a (Reference). A specimen of knit fabric made of dyed yarn was processed as described in Reference Example 5a. The test results of the finished specimen are shown in Table 2.

Example 8. A specimen of heavy woolen (art. 36460) with a surface density of 500 g/m^2 and premoistened as in Example 1 was exposed to the unfocused beam of a continuous-wave CO_2 laser to obtain a random design on the material.

The process parameters were:

laser output power	5-130 W
distance between laser and specimen	0.4 m
specimen travel speed	0.01-1.3 m/s

The fabric then was cleaned as in Example 2.

Example 8a (Reference). A specimen of heavy woolen (art. 36460) was screen-printed using a dye with a composition of:

caustic soda	200
thickening agent (indalka) 3%	600
water	up to 1000.

The specimen then was dried and steamed for 5-7 min at 160°C. After this, the specimen was rinsed to remove the disintegrated fibers:

(M-v 1:30)

flowing water	10 min
soaping TMS 2 g/liter at T 80°C	
rinsing at T 60°C	
rinsing in flowing water	10 min

The test results for the physico-mechanical properties of the specimen are shown in Table 2.

Example 9. A random design was applied using the beam of a continuous-wave CO_2 laser to a premoistened specimen of heavy

mixed woolen (art. 4646, 62% wool, 23% rayon, 15% kapron) with a surface density of 480 g/m^2. The process parameters for the laser treatment were the same as in Example 9. The subsequent treatment was the same as in Example 1.

Example 9a (Reference). A specimen of heavy mixed woolen (art. 4646) was screen-printed using a dye with a composition of:

caustic soda	200
thickening agent indalka (3%)	600
water	up to 1000.

The specimen then was dried and steamed for 5-7 min at 160°C. After this, the specimen was rinsed to remove the disintegrated fibers:

(M.v. 1:30)

flowing water	10 min
soaping TMS (2 g/liter) at T 80°C	10 min
rinsing at T 60°C	10 min
rinsing in flowing water	10 min

The test results for the physico-mechanical properties are shown in Table 2.

As follows from the physico-mechanical test results shown in Table 2, the method produces good quality, with the colorfastness rating of the patterns applied using this method being 0.5-1 higher than those made by the reference method, and the strength properties being 15-20% higher for colored patterns and 50% higher for three-dimensional patterns.

The method of making patterns is economical and environmentally clean. It uses less water, steam, electricity, and chemicals. It eliminates at least three process operations and improves the productivity of labor and equipment. The elimination of process operations which use chemicals and involve the removal of unfixed dye, resist chemicals, and discharge chemicals makes it possible to eliminate the need for wastewater treatment facilities. The method does not require additional specially equipped production facilities and therefore can be used in existing garment and footwear factories, and consequently patterns can be applied to finished articles.

CLAIM

A method of making patterns on long material by exposing certain areas of the material to heat and subsequent processing, characterized by the fact that in order to expand the technological capabilities, the material is moistened to a residual moisture content of 45-50% before the exposure to heat, which is provided by the radiation of a CO_2 laser with an output power of 10-100 W and a wavelength of 10.6 μm.

Table 1. Physico-Mechanical Properties of Materials With Colored Patterns.

(1) Пример 1

(2) Вид обработки образца	(3) Режим обработки		(6) Устойчивость окраски в баллах, К				(12) Разрывная нагрузка полоски ткани размером 50x200 мм, Н		(15) Удлинение при разрыве полоски ткани размером 50 x 200 мм, %	
	Мощность облучения, Вт (4)	Относительная скорость перемещения, м/с (5)	к мылу при кипячении (7)	дист. вода (8)	к трению (9) сухому (10)	к трению (9) мокрому (11)	основа (13)	уток (14)	основа (13)	уток (14)
(16) Без отделки	-	-	-	-	-	-	232,4	229,7	15,2	16,9
(26) лазерная	5	0,01	-	-	-	-	232,4	229,7	15,2	16,9
	10	0,1	5	5	5	5	232,4	229,7	15,2	16,9
	50	0,5	5	5	5	5	231,2	229,5	15,1	16,9
	100	1	5	5	5	5	231,0	229,5	15,0	16,8
	130	1,3	5	5	5-4	5-4	230,7	229,5	14,9	16,8
(17) Пример 1а (базовый)	-	-	5	5-4	4	4	2[illegible]0,9	229,1	14,9	16,7
									Пример 2 (21)	
(16) Без отделки/ (26) лазерная	-	-	-	-	-	-	256,8			19,8
	5	0,01	-	-	-	-	256,8			19,8
	10	0,1	5	5	5	5	256,8			19,8
	50	0,5	5	5	5	5	256,6			19,7
	100	1	5	5	5	5	256,6			19,6
	130	1,3	5	5-4	5-4	4	256,3			19,4
(18) Пример 2а (базовый)	-	-	5	4	4	4	251,4			19,2
									(22) Пример 3	
							(23) по длине	(24) по ширине	(23) по длине	(24) по ширине
(16) Без отделки/ (26) лазерная	-	-	-	-	-	-	210,2	208,7	18,7	19,2
	5	0,01	-	-	-	-	210,1	208,7	18,7	19,2
	10	0,1	5	5	5	5	210,0	208,5	18,7	19,0
	50	0,5	5	5	5	5	209,5	208,1	18,5	18,9
	100	1	5	5	5	5	209,1	207,8	18,4	18,9
	130	1,3	5	5-4	5-4	4	209,1	207,5	18,5	18,8
(19) Пример 3а (базовый)	-	-	5	4	5-4	4	208,9	207,4	18,2	18,8
									(25) Пример 4	
(16) Без отделки/ (26) лазерная	-	-	-	-	-	-	1,4		35	
	5	0,01	-	-	-	-	1,4		35	
	10	0,1	-	-	5	5	1,4		35	
	50	0,5	-	-	5	5	1,4		35	
	100	1	-	-	5	5	1,4		35	
	130	1,3	-	-	5	5-4	1,4		35	
(20) Пример 4а (базовый)	-	-	-	-	4	4-3	1,4			

Key: (1) Example 1; (2) Type of processing; (3) Processing conditions; (4) Laser output power, W; (5) Relative travel speed, m/s; (6) Colorfastness rating, units; (7) boiling soap solution; (8) distilled water; (9) abrasion; (10) dry; (11) wet; (12) Breaking load of 50 x 200 mm fabric strip, N; (13) warp; (14) weft; (15) Elongation at breaking of 50 x 200 mm fabric strip, %; (16) Unprocessed; (17) Example 1a (Reference); (18) Example 2a (Reference); (19) Example 3a (Reference); (20) Example 4a (Reference); (21) Example 2; (22) Example 3; (23) lengthwise; (24) widthwise; (25) Example 4; (26) Laser.

Table 2. Physico-Mechanical Properties of Materials With Three-Dimensional Patterns.

(2) Вид обработки образца	(3) Показатели работы лазера		(6) Разрывная нагрузка полоски ткани размером 50x200 мм, Н		(9) Удлинение при разрыве полоски ткани размером 50 x 200 мм, %	
	Мощность излучения, Вт (4)	Относительная скорость перемещения, м/с (5)	основа (7)	уток (8)	основа (7)	уток (8)
					(1) Пример 5	
(10) Без отделки	-	-	332,5	330,3	16,6	17,1
лазерная (20)	5	0,01	332,0	330,2	16,3	16,8
	10	0,1	330,7	329,6	16,0	16,6
	30	0,3	329,2	327,8	15,9	16,1
	100	1	327,9	325,7	15,7	15,9
	130	1,3	222,3	221,2	14,1	14,9
(11) Пример 5а (базовый)	-	-	195,1	191,4	5,4	5,8
					Пример 6 (16)	
(10) Без отделки	-	-	497,6	495,3	17,5	18,0
лазерная (20)	5	0,01	491,3	489,5	17,5	18,0
	10	0,1	491,0	488,7	17,3	17,9
	50	0,5	490,7	485,3	17,3	17,9
	100	1	489,2	401,5	17,0	17,7
	130	1,3	350,2	245,1	14,9	15,0
(12) Пример 6а (базовый)	-	-	245,7	192,6	6,9	7,2
					Пример 7 (17)	
(10) Без отделки	-	-	458,7		22,5	
лазерная (20)	5	0,01	458,0		22,5	
	10	0,1	456,3		22,5	
	50	0,3	455,5		22,4	
	100	1	452,9		22,3	
	130	1,3	349,2		18,5	
(13) Пример 7а (базовый)	-	-	215,6		15,1	
					(18)	
(10) Без отделки	-	-	248,8	192,1	17,2	17,3
лазерная (20)	5	0,01	248,0	191,5	17,2	17,2
	10	0,1	247,7	191,2	17,1	17,1
	50	0,5	247,4	190,9	17,0	17,0
	100	1	247,0	190,1	17,0	17,0
	130	1,3	115,9	105,5	14,8	15,0
(14) Пример 8а (базовый)	-	-	111,2	46,4	5,7	5,2
					Пример 9 (19)	
(10) Без отделки	-	-	347,1	217,7	25,2	26,7
лазерная (20)	5	0,01	347,0	217,5	25,2	26,5
	10	0,1	346,8	216,4	25,0	26,0
	50	0,5	346,3	215,7	25,0	25,7
	100	1	346,1	214,9	24,9	25,5
	130	1,3	295,1	214,9	19,5	19,7
(15) Пример 9а (базовый)	-	-	212,3	115,1	13,8	14,0

Key: (1) Example 5; (2) Type of processing; (3) Laser operating parameters; (4) Output power, W; (5) Relative travel speed, m/s; (6) Breaking load of 50 x 200 mm fabric strip, N; (7) warp; (8) weft; (9) Elongation at breaking of 50 x 200 mm fabric strip, %; (10) Unprocessed; (11) Example 5a (Reference); (12) Example 6a (Reference); (13) Example 7a (Reference); (14) Example 8a (Reference); (15) Example 9a (Reference); (16) Example 6; (17) Example 7; (18) Example 8; (19) Example 9; (20) Laser.

Compiled by A. Romanova
Editor, N. Kozlova
Technical Editor, M. Khodavich
Proofreader, L. Veskid

Order No. 908/DSP 172 copies Approved
VNIIPI of the State Committee for Inventions and Discoveries
of the USSR State Committee for Science and Technology
113035, Moscow, Zh-35, Raushskaya nab., d. 4/5

"Patent" Production-Publishing Combine,
Uzhgorod, ul. Gagarina, 101